

For Reference

NOT TO BE TAKEN FROM THIS ROOM

THE EFFECTS OF SOIL AMENDMENTS ON THE PHYSICAL
STRUCTURE OF SOLODIZED SOLONETZ SOILS
UNDER IRRIGATION

A.L. Mathieu, B. Sc.

University of Alberta

April 1954

Ex LIBRIS
UNIVERSITATIS
ALBERTAENSIS





Digitized by the Internet Archive
in 2018 with funding from
University of Alberta Libraries

<https://archive.org/details/Mathieu1954>

ABSTRACT

Experimental plots were laid out at Youngstown in 1952 to determine the effects of certain soil amendments and cultural practices on the physical structure of solodized solonetz soils under irrigation. The treatments used were: sulphur, gypsum, krillium, manure and deep cultivation, and these were compared with an irrigated check and a dry check treatment.

Field studies included grain height measurements, yield data, and penetrometer data. Laboratory investigations consisted of mechanical analyses, aggregate analyses, soluble salt content, permeability and porosity measurements and nitrogen determinations.

Field and laboratory studies showed a large variation in physical and chemical properties both within and between the plots. These variations masked treatment effects during the first year, and the plots are still too young to draw conclusive results. Penetrometer data did provide useful information on the physical properties of the soil as affected by treatments. June and September penetrometer data were compared as well as the hardness of surface soil. In 1953 the sulphur, manure and gypsum treatments did significantly improve crop yields but only gypsum, sulphur and krillium improved the physical structure of the soil.

1954
#15

THE UNIVERSITY OF ALBERTA

THE EFFECTS OF SOIL AMENDMENTS ON THE PHYSICAL
STRUCTURE OF SOLODIZED SOLONETZ
SOILS UNDER IRRIGATION

A DISSERTATION
SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

FACULTY OF AGRICULTURE
DEPARTMENT OF SOILS

by

A. L. MATHIEU, B. Sc. (Alta.)

EDMONTON, ALBERTA.

APRIL, 1954.

ACKNOWLEDGMENT

Deep appreciation and grateful acknowledgment are expressed to the following:

Dr. J. A. Toogood, Associate Professor of Soils, University of Alberta, for his encouragement, and valuable advice in planning this study, and for helpful criticisms in the preparation of the manuscript;

Dr. J. D. Newton, Head of the Department of Soils, University of Alberta, for guidance and inspiration at all times;

Dr. C. F. Bentley, Associate Professor of Soils, University of Alberta, for advice, and for help in photographic work;

Members of the Soils Department, and other members of the Faculty of Agriculture who were consulted from time to time, for suggestions and assistance;

T. W. Peters and A. Kjearsgaard, Alberta Soil Survey, for their co-operation on soil survey information;

R. A. Milne, Soil Chemist, P.F.R.A., for assistance in soluble salt determinations;

The Zinn family, Youngstown, near whose farm the plots were located, for their co-operation, kindness and Western hospitality;

K. Krogman, in charge of the Dominion Experimental Station plots at the same location, for co-operation and

suggestions in plot work;

Research Council of Alberta for providing the funds that enabled this research to be carried on and for providing financial assistance to the writer for 1952 and 1953;

The United Farmers of Alberta for providing the writer with financial assistance through the Robert Gardiner Memorial Scholarship, awarded to the writer for 1952-53.

The Tegler Trustees, for providing the writer with financial assistance through the Robert Tegler Research Memorial Scholarship awarded to the writer for 1952-53 and 1953-54.

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
REVIEW OF LITERATURE	
The origin and nature of solodized solonetz soils	4
Solodized solonetz soils in south eastern Alberta	8
Relationship between solodized solonetz areas and underlying geology in south eastern Alberta	11
Methods of improving the physical characteristics of saline and alkali soils	13
Methods of evaluating the physical structure of soils	20
Soil Aggregate analysis	21
Porosity determination	24
Soil penetrometer	26
NATURE OF THE PRESENT STUDY	28
METHODS USED	29
The field experiments	29
History of the plots	33
Field studies	35
Yield determinations	35
Height measurements	35
Penetrometer studies	35

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

METHODS USED

Laboratory Studies	42
Aggregate analysis	43
Mechanical analysis	44
Permeability and porosity studies	44
Soluble salts	44
Nitrogen determinations	47

RESULTS

Field results	48
Laboratory results	50

DISCUSSION	82
CONCLUSIONS	88
BIBLIOGRAPHY	90
APPENDIX	96

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

TABLES

	Page
	<hr/>
1. Variations in sieve size, stroke, RPM, and time of sieving used by different analysts for aggregate analysis	23
2. Youngstown plots. Barley yield data in full and analyses of variance	56
3. Youngstown Plots. Wheat yield data in full and analyses of variance	58
4. Wheat yield in grams of each square yard sample in part of the Youngstown plots, 1953..	60
5. The average depth of Isoprobes	61
6. Penetrometer data. Depth of isoprobes. June 1953 and analysis of variance	62
7. Penetrometer data. Depth of isoprobes. September 1953 and analysis of variance	64
8. Penetrometer data. Resistance factor for 1st inch of surface soil. September 1953 and analysis of variance	68
9. Penetrometer data. Resistance factor for 2nd inch of surface soil. September 1953 and analysis of variance	70
10. Penetrometer data. Resistance factor for 3rd inch of surface soil. September 1953 and analysis of variance	72

Page 1

1. The first part of the report is a general introduction to the project. It describes the purpose of the study and the objectives that were set at the beginning. It also provides a brief overview of the methodology that was used.
2. The second part of the report is a detailed description of the methodology that was used. It includes a description of the data collection methods, the data analysis methods, and the statistical tests that were used.
3. The third part of the report is a description of the results that were obtained. It includes a description of the data that was collected, a description of the data analysis results, and a description of the statistical test results.
4. The fourth part of the report is a discussion of the results. It discusses the implications of the results and the limitations of the study. It also provides some suggestions for future research.
5. The fifth part of the report is a conclusion. It summarizes the main findings of the study and provides some final thoughts on the project.
6. The sixth part of the report is a list of references. It includes a list of all the sources that were used in the study.
7. The seventh part of the report is an appendix. It includes a list of all the data that was collected and a list of all the data analysis results.
8. The eighth part of the report is a list of figures. It includes a list of all the figures that were used in the study.
9. The ninth part of the report is a list of tables. It includes a list of all the tables that were used in the study.
10. The tenth part of the report is a list of appendices. It includes a list of all the appendices that were used in the study.

11. Aggregate analysis data 1953 and mean weight diameter	74
12. Soluble salts in several profile soil samples from Youngstown plots	78
13. Total nitrogen determinations of some Youngstown plot soils	81
14. Geological formations in Alberta	97

PLATES

	<u>Page</u>
I. Geological map of Red Deer River Diversion Project	12
II. Youngstown plot vegetation prior to plowing, 1952	30
III. The Hemaruka profile	36
IV. The self recording soil penetrometer full view ...	38
V. The self recording soil penetrometer - graph carriage	39
VI. The master graph and table for penetrometer graph roll	39
VII. Apparatus for vacuum wetting of the sample for aggregate analyses	45
VIII. Wet sieving equipment used for aggregate analyses	46
IX. Height measurements of barley at Youngstown plots September, 1952	53
X. Height measurements of wheat at Youngstown plots September, 1953	54
XI. Youngstown plot yields	55
XII. A three dimensional model of the Youngstown plots showing plot relief and position of June isoprobes	66
XIII. Hardness and aggregate analysis of surface soil ..	67
XIV. Mechanical analysis of surface soil from each plot	76

XV.	Physical characteristics of an eroded pit and an adjacent permeable profile	77
XVI.	Profile diagram of plot relief and June and September isoprobes. 1953. Range I.	96
XVII.	Profile diagram of plot relief and June and September isoprobes. 1953. Range II.	97
XVIII.	Profile diagram of plot relief and June and September isoprobes. 1953. Range III.	98
XIX.	Profile diagram of plot relief and June and September isoprobes. 1953. Range IV.	99

INTRODUCTION

Irrigation experience shows that there have been many successes and many failures. Scofield (47) affirms that the largest number of failures in irrigation agriculture has been due to unfavourable conditions of soil, water supply and drainage, not realized in advance. Irrigation projects would stand the best chance of success when all the physical factors are known and are carefully weighed on the economic balance before construction is begun. Successful irrigation projects have certainly transformed the productivity and economy of many parts of the world with far reaching beneficial effects; unsuccessful projects have left many communities and states burdened with debt, lowered standards of living and disrupted community facilities.

The proposed Red Deer river diversion irrigation project, or as it is sometimes termed, the Wm. Pearce irrigation project is designed to irrigate a semi-arid area north and south of Youngstown in south-eastern Alberta (see Plate I).

Several survey parties have covered the area. Wyatt and Newton (64) in their soil survey report of the Sounding Creek sheet described the area and discussed the predominance of the "blow out" phase loam in the now proposed irrigation area. Odynsky (37) outlined the solonetz areas in Alberta. It will be observed (see Plate I) that a large portion of the

It is a very common mistake to suppose that the

only reason for the existence of the

is the fact that the

has been the

and therefore, the

will find the

which the

between the

the

the

the

the

the

the

the

the

the

the

the

the

the

the

the

proposed project is in his solonetz belt. Preliminary irrigation surveys have been completed by Prairie Farm Rehabilitation Administration engineers and the area of land that can be irrigated by gravity and by pump has been determined. The Alberta Soil Survey has recently completed a semi-detailed soil survey of the proposed irrigation project. Their survey indicates that approximately fifty per cent of the irrigable soil is classified as solodized solonetz.

While solodized solonetz soils occur in other irrigated areas, the geological formations underlying the glacial till differ. The permanence of the proposed irrigation project may well depend on the behaviour of the solodized solonetz under the particular conditions to be found in the proposed project. Some solodized solonetz soils in Alberta are under irrigation, especially in the vicinity of Brooks (see Plate I). Irrigation reclamation is apparently successful in that area due mainly to a permeable underlying C horizon. However, as Odynsky (op. cit.) points out, it is unwise to assume on the basis of the success in the Brooks area that all solodized solonetz soils are suitable for irrigation.

Recognizing the problems associated with the irrigation and improvement of solodized solonetz soils, the authorities in charge felt that an investigation of these soils was essential before construction of the project was commenced. The Research Council of Alberta and the Soils

Department, University of Alberta in co-operation with the Dominion Experimental Station, Lethbridge commenced experimental plots in 1952 near Youngstown. These experimental plots were designed to study methods and practices of irrigating and improving solodized solonetz soils. This thesis is a report on the effects of soil amendments on the physical structure of the solodized solonetz soils under irrigation at the Youngstown plots.

REVIEW OF LITERATURE

The Origin and Nature of Solodized Solonetz Soils

Lyon and Buckman (32) Pettijohn (38), as well as many other writers of texts in soil science and geology discuss the many sources of soluble salts. The direct source of salt constituents is the primary minerals found in soils and in exposed rocks of the earth's crust from which soil material is formed. During the process of weathering, salt constituents are gradually released and dissolved by water. The ocean may be considered as the source of salts as in the case where a soil's parent material consists of marine deposits which were laid down during earlier geologic periods. Water acts as a carrier for salts, and saline soils generally occur therefore in areas which are the recipients of salts brought in by ground water, drainage water, or irrigation.

A clear concept of the terms saline, alkali, solonchak, solonetz and soloth is important. The terms saline and alkali are generally used in literature to indicate the soluble salts and the degree of alkalinity in soils. The Riverside Salinity Laboratory (40) defines saline and alkali soils on the basis of the conductivity of a saturation extract and the exchangeable sodium percentage. The terms solonchak, solonetz, and soloth,

THE HISTORY OF THE

REPUBLIC OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

THE HISTORY OF THE UNITED STATES OF AMERICA

according to the U.S.D.A. Soil Survey Manual (53) refer to genetic groups of soils. Differentiation is based primarily on morphology and genesis.

The processes involved in the formation of saline and alkali soils as discussed by Byers et al (6) are: salinization, desalinization, alkalization and dealkalization and these will be reviewed briefly at this point.

Salinization:-- denotes the process of salt accumulation in soils. This process can occur on practically any kind of soil and gives rise to the development of saline soils - sometimes called solonchak. The accumulation of soluble salts, according to Richards (40) is due mainly to an arid climate, poor drainage and irrigation. Russell (44) explains how the high evaporation rates and low rainfall of an arid climate are responsible for localized patches of efflorescence on the surface of saline soils. Poor drainage is due to the presence of impermeable layers which restrict water movement. Richards states that these impermeable layers may be due to a clay pan, a caliche layer or a silica hardpan. A saline soil may be produced by the addition of salts to a non-saline soil. Richards, Chang (8) and Russell (op. cit.) explain how salinization of a soil may be caused by irrigation due mainly to special features of topography, high amounts of salts in irrigation waters and the failure to recognize the need for establishing artificial drainage.

Solonchaks are sometimes called "structureless" soils and lack prismatic and blocky structure. The term, solonchak, is also modified by the name of the dominant salt present. The U.S.D.A. Soil Survey Manual (op. cit.) states that if a solonchak has calcium as the dominant salt, it is called a calcium solonchak. With improved drainage and removal of salts the calcium solonchak gradually changes over to a normal soil while the sodium solonchak may change to a solonetz or a solodized solonetz and perhaps to a soloth before developing into a zonal soil.

Saline soils usually have a favourable structure and are readily permeable to water and air. This favourable condition is due to the presence of excess salts and the absence of appreciable amounts of sodium on the exchange complex which flocculates the colloids.

Desalinization and alkalization -- involves the removal of salts and the entrance of sodium into the base exchange complex. Strongly alkaline soils are formed as a result of the hydrolyzing of the sodium clays. This results in a deflocculation of the soil colloids. The eluviation of the clay follows deflocculation resulting in the formation of a very hard prismatic or columnar B horizon. This process is sometimes called "solonization" and the resulting soil is called a solonetz.

Dealkalization -- is the process in which the excess sodium of a solonetz is gradually removed by leaching. The upper part of the soil may become somewhat acid with a deep grey layer over an acid blocky B horizon. Such soils are called soloth and the process of change of solonetz to soloth is termed "solodization".

There are many differences of opinions among soil scientists the world over regarding the genesis and classification of saline and alkali soils. These differences of opinions are mainly the result of different concepts of the essential characteristics of solonetz as described by Russian scientists. Glinka (18) has taken the view that the solonetz is distinguished by certain morphological features and that the possessing of certain chemical characteristics is secondary. De Sigmond (11) postulated that the solonetz should have not less than ten to fifteen per cent of its base exchange capacity taken up by sodium. The papers of MacGregor and Wyatt (34) Riecken and Stalwick (42) and Bentley (4) all refer to soils having solonetz or solodized solonetz characteristics in which sodium does not dominate the base exchange complex. Russell (op. cit.) maintains that the B horizon of the solonetz is probably more indicative of the clay mineral than of exchangeable sodium or magnesium. Recent work mentioned by Grim (20) indicates that illite and montmorillonite are the dominant clay minerals of solonetz soils, no kaolinite being found as a rule.

Definitions of solonetz, solodized solonetz and soloth have been proposed. Bentley (op. cit.) states that the distinguishing feature between solonetz and solodized solonetz is given as the greyish, leached, platy structured, acidic A₂ horizon which is found in the latter but not in the former. He proposes that they be distinguished as follows: that the solonetz has less than six inches of A horizon above a columnar B horizon while the solodized solonetz has an A horizon of more than six inches. The U.S.D.A. Soil Survey Manual (op. cit.) states that soloth soils are uncommon while the intergrade soils called the solodized solonetz are common. These soils have the leached A horizon of the soloth and the non-acid columnar B horizon of the solonetz. The manual also states that a solonetz with neither excess salts in the solum nor suggestion of solodization in the A horizon is rare. A soil may go from a solonchak to a solodized solonetz without ever being a typical solonetz.

Solodized Solonetz in South Eastern Alberta

The Alberta Soil Survey have classified solodized solonetz soils on the basis of U.S.D.A. Soil Survey Manual definitions (op. cit.). The following is a generalized description of a Hemaruka loam (brown solodized solonetz) taken from Alberta Soil Survey files:-

<u>Inches</u>			<u>pH</u>
3 - 6	A ₁	loose brown loam.	7.5 - 5.6
1/2 - 1 1/2	A ₂	loose brown loam, mildly platy	7.1 - 6.5
5 - 10	B ₂	very dark clay. Columnar with round or flat tops.	7.5
4 - 8	B ₃	low to medium lime concentrations	7.5
SO ₄ (salt) at 25"		variable concentration	8.0
C at average 30"		a heavy textured till containing chunks of coal, ironstone and shale fragments.	

Solodized solonetz soils have noticeable distinguishing features. The A horizons are variable in depth; the B horizons have well developed columnar structure with round or flat tops; the contact between A and B horizon is very distinct; and there is also an extremely leached, greyish horizon above the columnar B horizon. This platy A₂ horizon may vary in thickness from a mere film to two or three inches. Frequently the leached surface layer is eroded away exposing the hard clay of the B horizon in the bottom of shallow pits. These eroded pits have been given local names such as slick spots and blowouts. The physical behaviour of solodized solonetz

soils when wet or dry is also a very distinguishing feature. The top of the B horizon becomes sticky and impervious when wet and very hard when dry. These conditions, in general, are unsatisfactory for cultivation and plant growth and prompt the doubts in the minds of many people as to the suitability of such a soil for irrigation.

McGregor (33) investigated the solodized solonetz soils in the brown soil zone of south-eastern Alberta. He reported that these soils formed as a result of limited precipitation and a topography which tends to give incomplete drainage of relatively large areas. After studying the base exchange in these and adjacent normal soils he concluded that:

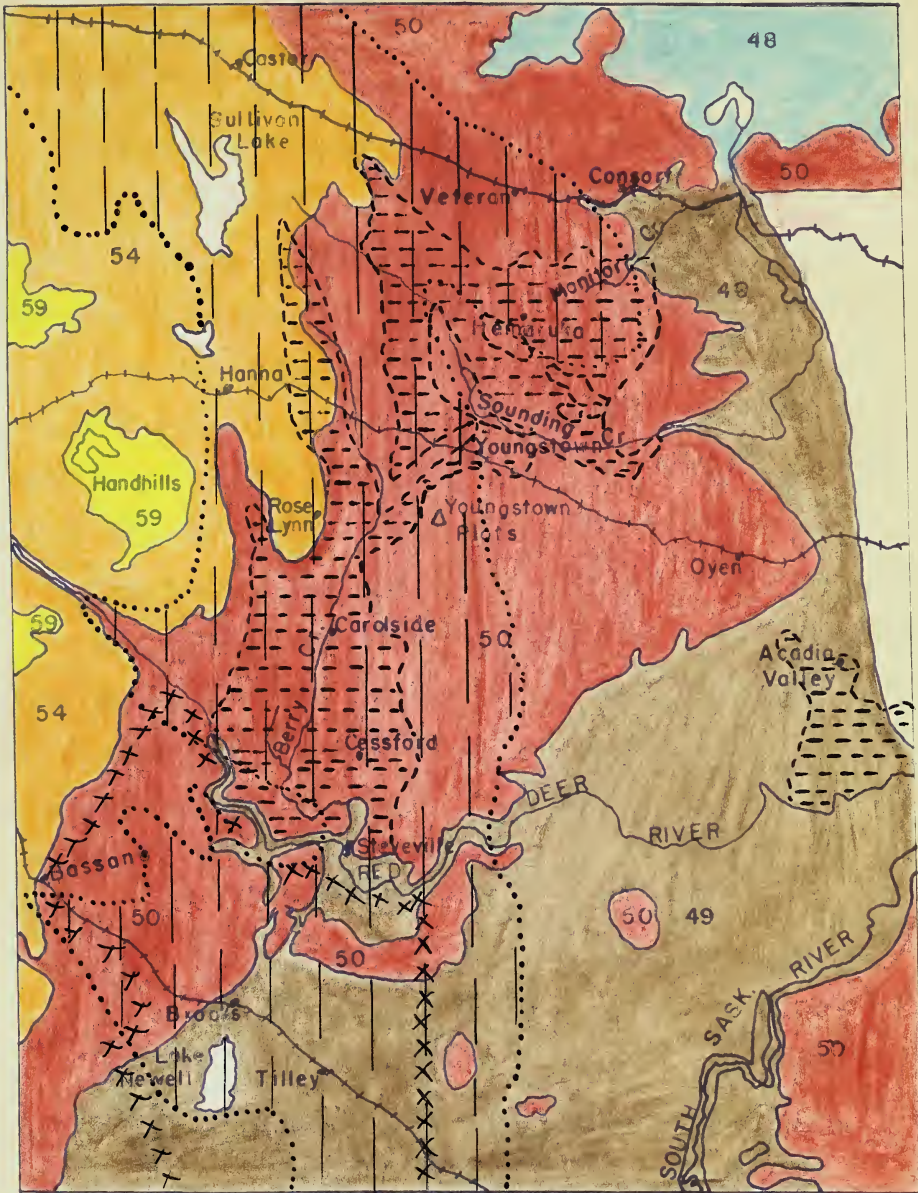
- (1) The amount of exchangeable sodium in solodized areas was considerably lower than calcium or magnesium.
- (2) A correlation existed between the degree of solonization and the amount of exchangeable sodium, a correlation also found by Westin (62) and Riecken and Stalwick (42).
- (3) A higher concentration of water soluble sodium was found in solonized profiles than in normal profiles.

Relationship Between Solodized Solonetz Areas and Underlying
Geology in South Eastern Alberta.

The suggestion of a correlation between the occurrence of solodized solonetz soils and the underlying formation is not new. Kellogg (25) and Bentley (op. cit.) associated solonetz areas with parent material of shallow glacial till underlain by marine shales. The Bearpaw formation^{*} underlies most of the solodized solonetz area in south eastern Alberta as outlined by Odynsky (see Plate I). Allan (1) and Wyatt and Newton (64) observed the abundant amount of calcium sulphate in the formation and also some sodium and magnesium sulphates. A report on subsurface water resources in the Sounding creek area by the Department of Lands and Mines of Alberta indicates that the predominant salts in water wells in the Bearpaw formation are mainly sodium chloride and sodium sulphate. Allan (2) points to imperfect drainage, shallow glacial till and sulphate salts as responsible for the alkali soils associated with the Bearpaw formation. From the facts presented, it would appear that there is a definite relationship between solodized solonetz soils and the Bearpaw formation in south eastern Alberta and it is worth noting that while almost the entire Red Deer project overlies Bearpaw bedrock much of the Eastern Irrigation District east of Brooks is over a different formation. Differences may therefore be expected in the adaptability of these two areas to irrigation practices.

* For description of geological formations in Alberta see Table 14 in Appendix.

GEOLOGICAL MAP OF RED DEER RIVER DIVERSION PROJECT



LEGEND

- | | |
|---|--|
| 59 PASKAPOO FORMATION | 49 OLDMAN FORMATION |
| 54 EDMONTON FORMATION | 48 VARIEGATED AND PALE BEDS |
| 50 BEARPAW FORMATION | ODINSKY'S SOLONETZ BELT |
| RED DEER RIVER DIVERSION PROJECT | EASTERN IRRIGATION DISTRICT |

Methods of Improving the Physical Characteristics of Saline and Alkali Soils

Richards (40) states that the improvement of saline and alkali soil involves practices and methods for the removal of excess salts and exchangeable sodium from the soil, and the improvement of the structure and tillage qualities of the soil. The removal of excess soluble salts is sometimes not sufficient to restore such soils to productivity. Weiser (61) says that according to Bradfield it is essential to restore the normal calcium-sodium ratio on the exchange complex in order to regain the normal physical condition of these soils.

The writer lists below the methods of Richards (op. cit.) and other writers (5, 7, 16, 21, 22, 23, 29, 30, 44, 49, 50 and 66) for improving the chemical and physical properties of saline and alkali soils:

A. Soil drainage by lowering the water table.

- (1) Deep open ditches
- (2) Tile lines
- (3) Pumping from wells

B. Improving the permeability of the soil profile.

- (1) Soil amendment treatments
- (2) Soil management practices

A large number of soil amendments have been tried and these may be listed as follows:

I. Chemical Amendments

(a) Inorganic chemicals

- (1) Sulphur
- (2) Sulphuric acid
- (3) Gypsum
- (4) Calcium carbonate
- (5) Aluminium sulphate
- (6) Calcium sulphate
- (7) Fertilizers
- (8) Calcium nitrate
- (9) Ammonium sulphate
- (10) Calcium oxide
- (11) Calcium chloride
- (12) Iron sulphate

(b) Organic chemicals

- (1) Krilium
- (2) Alconite
- (3) Molasses

II. Physical Treatments

(a) Special tillage

- (1) Deep ploughing
- (2) Deep cultivation

(b) Miscellaneous

- (1) Dynamite

(b) Miscellaneous

- (2) Reclamation by use of deep rooted crops.
- (3) Electrical treatment such as electrodialysis.

Likewise many management schemes have been tried out, the more important being:

(a) Crop rotation and management

- (1) The use of salt tolerant crops
- (2) The incorporation of legumes
- (3) The application of fertilizers
- (4) The application of manure

(b) Cultural practices

- (1) Moisture content of soil maintained at optimum
- (2) Use of special cultural implements.

(c) Irrigation practices

- (1) Proper irrigation methods
- (2) Correct water application

Soil drainage lowers the water table and also improves the permeability of the soil profile. Richards (op. cit.) stresses adequate drainage as the first essential in any reclamation program. A classical example of soil drainage is the reclamation of lakes in Holland as explained by Zuur (66). On the basis of experiments in California, Kelley (26) concludes that it is economically feasible to reclaim almost any

alkali soil provided it can be efficiently drained and an adequate supply of irrigation water is available.

The application of inorganic chemical amendments has been used by many investigators to improve the permeability and crop yield of saline and alkali soils. Hauser (22) and Russell (44) have reported that gypsum improved the permeability of certain soils. Bower (5) states that lime decreased while gypsum and sulphur increased infiltration rates, that sulphur tended to lower hay yields while gypsum and lime had no effect. The sulphur treatment gave the highest increase in the alfalfa stand and encouraged root growth downwards to a depth of forty inches in an experiment conducted by Fitts et al (14) using sulphur, gypsum and calcium chloride treatments at varying rates on slick spots. Shawarbi (49) mentions that aluminum sulphate, sulphuric acid and calcium sulphate reduced the alkalinity on Hungarian soils while calcium carbonate had no beneficial effects. In Kelley's experiments (26) a black alkali soil at Fresno was reclaimed by the use of gypsum, by sulphur, by iron sulphate or by alum. Russell (op. cit.) and Zuur (op. cit.) explain how land in Holland is reclaimed from the sea. Due to the large amounts of calcium carbonate in the sedimentary deposits the sodium soil is changed to a calcium soil on drainage and good soil structure is attained. Hubbell and Stubblefield (23) state that all the amendments in their experiment except calcium carbonate improved the percolation rate,

the following information was obtained from the records of the

Department of the Interior, Bureau of Land Management, Washington, D. C.

and the following information was obtained from the records of the

Department of the Interior, Bureau of Land Management, Washington, D. C.

and the following information was obtained from the records of the

Department of the Interior, Bureau of Land Management, Washington, D. C.

and the following information was obtained from the records of the

Department of the Interior, Bureau of Land Management, Washington, D. C.

and the following information was obtained from the records of the

Department of the Interior, Bureau of Land Management, Washington, D. C.

and the following information was obtained from the records of the

Department of the Interior, Bureau of Land Management, Washington, D. C.

and the following information was obtained from the records of the

Department of the Interior, Bureau of Land Management, Washington, D. C.

and the following information was obtained from the records of the

Department of the Interior, Bureau of Land Management, Washington, D. C.

and the following information was obtained from the records of the

Department of the Interior, Bureau of Land Management, Washington, D. C.

and the following information was obtained from the records of the

Department of the Interior, Bureau of Land Management, Washington, D. C.

and the following information was obtained from the records of the

Department of the Interior, Bureau of Land Management, Washington, D. C.

and the following information was obtained from the records of the

Department of the Interior, Bureau of Land Management, Washington, D. C.

and the following information was obtained from the records of the

that sulfuric acid increased the total soluble salts, that none of the treatments, including gypsum, calcium nitrate and an activated sludge (alconite), had any effect on the formation of water stable aggregates.

Certain organic compounds have been successfully used to improve the physical structure of saline and problem soils. Shawarbi (op. cit.) mentions the successful reclamation of alkali soils by molasses treatment. A soil conditioner developed by Monsanto chemical company and given the trade name Krilium has improved the physical structure of certain problem soils. Sherwood (50) observed improved soil workability, reduced soil crusting and effective erosion control in his Krilium experiments. Improved crop yield and quality was also observed. Chepil (9) found that Krilium increased soil permeability, produced good soil tilth, and increased the proportion of water stable aggregates. Many studies and experiments are underway to find the most efficient method of using Krilium. Haise et al (21) showed that there was a significant decrease in yield with increasing rates of Krilium. Laws (30) noticed that the conditioner was more effective as an aggregating agent on sandy loam and clay loam than on heavy clay soils. He also noticed that the presence of calcium carbonate in the soil inhibited the effectiveness of the soil conditioner. Krilium shows spectacular ability to improve the physical structure of

soil. Its relation to plant growth and soil stabilization is not yet fully known.

The combination of physical and chemical amendments has great possibilities for improving the physical and chemical condition of saline and alkali soils. Russell (op. cit.) and Richards (op. cit.) report that the permeability of a soil can sometimes be increased by deep ploughing, particularly if gypsum is added or if gypsum is present in the soil. Smith (52) showed that subsoiling following placement of lime in a plow furrow improved the root system of clover. The combination of subsoil placement of lime and fertilizer improved sugar beet yield and infiltration rates in an experiment conducted by Martinez and Lugo-Lupez (35).

Novel methods have been used in the past for reclaiming alkali soils. Experiments have shown that dynamite will not improve the permeability of hard pan clay soils in Kansas (7). Shawarbi (op. cit.) says that electrodialysis of alkaline soils holds vast possibilities.

Soil management practices offer perhaps the most practical solution for the improvement of saline and alkali soil. A good crop rotation is essential. Smith (op. cit.) stresses a fertility program aimed at maintenance of organic matter. Lyon and Buckman (op. cit.) stress the importance of green manures and salt tolerant crops for alkali control.

Odynsky (op. cit.) advises the growing of soil improving crops such as alfalfa and sweet clover with occasional deep ploughing. Zuur (op. cit.) found that fertilizer application was essential on reclaimed land. Bower (op. cit.) concluded that nitrogen and phosphorus were essential in the fertilization program.

Moist alkali soils usually present a cultural problem. Richards (op. cit.) warns that alkali soils are subject to puddling and should not be cultivated when wet. Laws (29) and Smith (op. cit.) mention that the subsoil will shatter satisfactorily only if the moisture content of the soil is less than 16 per cent. Gardner (16) states that the permeability of sodium saturated soil was restored by freezing and thawing only when calcium chloride was added to replace the sodium ion. He comments on the advantages of a cold climate in restoring the structure and permeability in the process of reclaiming soils that have been injured by sodium salts.

The proper use of water and the quality of irrigation water is important in irrigated areas. Richards (op. cit.) explains the proper irrigation methods and correct water applications in order to maintain a favourable salt balance in the soil without excessive leaching of plant nutrients.

The quality of water may affect the physical condition of the soil and also plant growth. Richards lists three important factors in irrigation water: total salt content, the soluble sodium percentage and the boron content.

Experiments and methods mentioned indicate that the improvement and reclamation of saline and alkali soils is a complex problem. Shawarbi (op. cit.) refers to Stebutt's discussion of soil dynamics in the evolution of alkaline soil. Stebutt is reported to claim that the reclamation treatment must change the chemical, physical and biological processes that are continuously occurring in a soil in such a way that the evolution of the soil will lead to a normal agricultural soil.

In summarizing these opinions and findings it is obvious that a program for successful handling of solodized solonetz soils under irrigation should probably include improvement of soil drainage, the addition of soil amendments and proper soil management. Variations in program would result from varying local conditions.

Methods of Evaluating the Physical Structure of Soils

Baver (3) reports that there are direct and indirect methods for evaluating soil structure. The direct methods involve macroscopic and microscopic observations but these methods have not been sufficiently perfected as yet to provide

a complete picture of soil structure. The indirect methods of evaluating soil structure include aggregate analyses, porosity and permeability determinations and penetrometer evaluations.

Soil Aggregate Analysis

Aggregate analysis has been stimulated by the advent of soil conditioners since some method of evaluating their effects was needed. Bayer (op. cit.) discusses various methods and states that an aggregate analysis aims to measure the percentage of water-stable secondary particles in the soil and the extent to which the finer mechanical separates are aggregated into coarser fractions. In general, Yoder's wet sieving technique (65) is the basis for most of the work done on this continent. The major problems in this type of analysis are:

- (1) Pre-treatment of the sample
- (2) Technique
- (3) Expressing the results in a meaningful way.

Pre-treatment of the Sample -- Time of sampling has an effect on aggregation. Gish (17) reports that the season of the year and moisture content of the soil at the time of sampling have a marked influence on aggregation. The sample is usually air dried before analysis. Slater (51) noticed no effect on aggregation when the sample was air dried in the laboratory. Pre-treatment of the sample before sieving has been done in

A. The first part of the report is devoted to a description of the work done during the year. It is divided into two main sections, the first of which deals with the work done in the laboratory and the second with the work done in the field.

Work done in the laboratory

The work done in the laboratory during the year has been devoted to the study of the properties of the various types of soil. It has been found that the properties of the soil vary with the type of soil and with the depth of the soil. The work has been divided into two main parts, the first of which deals with the study of the properties of the soil and the second with the study of the properties of the soil. The work has been done in the laboratory and in the field.

Work done in the field

The work done in the field during the year has been devoted to the study of the properties of the various types of soil. It has been found that the properties of the soil vary with the type of soil and with the depth of the soil. The work has been divided into two main parts, the first of which deals with the study of the properties of the soil and the second with the study of the properties of the soil. The work has been done in the laboratory and in the field.

several ways: wetting the sample by end over end shaking, spraying, wetting by capillary rise, rapid immersion, and by flooding in an evacuated flask. Nyhawan and Olmstead (36) found that treatment of samples before sieving greatly influenced the yield of aggregates larger than 0.2 mm. Van Bavel (60) in a recent publication criticizes vacuum wetting of the sample. He concluded that vacuum wetting of the sample introduced a large amount of random variation in the results of aggregate analysis and involved an extra amount of work. He does not recommend the use of vacuum wetting.

Technique -- Different wet sieving techniques used are suggested by Table 1. Van Bavel (op. cit.) recommends that the nature of the sieving apparatus is not important providing the specifications for the size of the sieves, frequency and strokes are met.

Expressing the Results in a Meaningful Way -- Schaller and Stockinger (46) indicate five ways for expressing aggregation data that have been in common use. These are: percentage aggregates greater than 2 mm., per cent greater than 1 mm., per cent greater than 0.25 mm., geometric mean, and mean weight diameter. They conclude that all methods are reliable, but greater accuracy is obtained by using geometric mean and mean weight diameter methods. Krumbein's (28) geometric mean and Van Bavel's (59) mean weight diameter both use a single value

TABLE 1

Variations in Sieve Sizes, Stroke, RPM,
and Time of Sieving, used by Different Analysts for Aggregate
Analysis

	<u>Yoder (65)</u>	<u>Woodruff (63)</u>	<u>Elson (13)</u>	<u>Russell (45)</u>	<u>U. of A.</u>
Sieve	5.0	6.7	8.0	5.0	4.0
sizes	2.0	4.0	5.0	2.0	2.0
in	1.0	2.0	2.0	1.0	1.0
mm.	0.5	1.0	1.0	0.5	0.5
	0.25	0.5	0.5	0.25	0.25
	0.10	0.25	0.25	0.10	0.125
		0.10	0.1		
Stroke	1 1/4"	4 7/8"	3 1/2"	1 1/2"	1 1/4"
R.P.M.	30	19	36	30	30
Time	30'	Varying	18'	30'	30'

to characterize the whole size distribution of the analysis. This has the advantage of rendering the data suitable for statistical analysis. Sherwood and Engebou (50), and Laws (30) have used wet sieving techniques to determine the effects of soil amendments on soil structure. Aggregation data are used to determine the effects of different soil treatments. Robinson and Page (43) state that reclamation of dispersed soil requires the use of soil amendments and organic matter. Gish and Browning (17) noticed that soil and crop management practices had a marked effect on soil aggregation data. Hubbell and Stubblefield (23) determined the effects of soil amendments on soil aggregation by aggregate analysis.

Porosity Determinations

Baver (op. cit.) reports that most soil porosity measurements are based upon determinations of the apparent specific gravity. The capillary, and non capillary porosity may be calculated from the volume, weight, moisture content and density of the soil particles. Uhland and O'Neal (58) outline a method for porosity determination using undisturbed soil core samples and a tension plate.

Permeability Determinations

Soil permeability may be defined as the capacity of the soil to transmit water and air. Permeability can be measured quantitatively on undisturbed soil cores in terms of percolation.

Uhland and O'Neal outline a technique. Rates of percolation are usually expressed in inches per hour.

A wide variety of equipment and procedures have been used in the past for obtaining undisturbed soil cores. Lutz (31) Swanson (55) Uhland (op. cit.) Kelly et al (27) Goode and Christian (19) have developed equipment for taking undisturbed soil core samples. Soil cores are obtained by hammering or jacking the core sampler into the soil. Some core samplers have a rotary cutting head. The number of hammer blows required to obtain a soil core is sometimes used as a guide for evaluating soil permeability. Edminster et al (12) compared different soil core samplers with a view to standardization. This investigation led to the adoption of the Uhland core sampler as standard for experiments in the south-eastern states. Uhland's technique in general is the basis for soil permeability determinations and evaluations.

Data obtained from permeability determinations are useful in several respects. Fletcher and Livingstone (15) studied the physical character of an artificially eroded soil under legume for 10 years with that of an adjacent uneroded area. Their data indicate that for the upper several inches of soil the legume has significantly lowered volume weight, increased total porosity, increased rate of surface water intake and increased air flow. Uhland (57) investigated the physical properties of soils with undisturbed soil cores, as modified by crops and management. His data show that deep rooted legumes such as

...the first ...
...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

...the first ...

kudzu and alfalfa increase the percolation rate for the entire soil profile.

Soil Penetrometer

A soil penetrometer consists mainly of a probe which is forced into the soil to measure soil consolidation.

Various types of penetrometers have been designed by soil scientists. The instruments have varied in design from simple hammer driven probes or impact penetrators (24,54 and 55) to devices with indicating or recording gauges (10,39,41 and 48).

Soil penetrometers have been used to locate compact profile layers, and determine soil hardness, measure soil moisture conditions and evaluate soil permeability. Culpin (10) noticed a close relationship between soil consolidation and the penetration of metal probes. Stone and Williams (54) measured soil hardness with their soil hardness gauge and suggested possible practical uses for the gauge. Reed (39) studied the effects of soil packing by tractors with a penetrometer. Shaw (48) concluded that soil moisture content in penetrometer evaluations was a greater factor in soil hardness than porosity. Jamison and Weaver (24) used penetrometer measurements to estimate soil prosity. Richards (40) felt that the usefulness of penetrometers had not been exploited enough in connection with profile studies. A particular advantage of a penetrometer, he says, is that it can be used under field conditions.

and the other two are the same as the first two.
The first two are the same as the first two.

THE FIRST TWO

The first two are the same as the first two.
The first two are the same as the first two.

The first two are the same as the first two.
The first two are the same as the first two.

The first two are the same as the first two.
The first two are the same as the first two.

The first two are the same as the first two.
The first two are the same as the first two.

The first two are the same as the first two.
The first two are the same as the first two.

The first two are the same as the first two.
The first two are the same as the first two.

The first two are the same as the first two.
The first two are the same as the first two.

The first two are the same as the first two.
The first two are the same as the first two.

The first two are the same as the first two.
The first two are the same as the first two.

The first two are the same as the first two.
The first two are the same as the first two.

The first two are the same as the first two.
The first two are the same as the first two.

In connection with Shaw's conclusion, mentioned above, it is obvious that moisture content of soils must be taken into account in interpreting penetrometer data. Where, however, a large number of penetrometer readings are made in a small plot area where moisture conditions are uniform this factor is probably of only minor importance.

It seems to me that the only way to
solve the problem of the future of the
United States is to find a way to
bring the people back to the United States.
I am sure that the people of the United States
will do this if we only give them the chance.
I am sure that the people of the United States
will do this if we only give them the chance.

NATURE OF THE PRESENT STUDY

Attention has been called in the Introduction to the predominance of solodized solonetz soils in the proposed Red Deer irrigation project, and a brief description given of the problem at hand. Various methods of improving the physical condition of such soils were reviewed and also the results of such methods in different areas. The present study had as its object the testing of several soil amendments and the determination of their effects on the physical structure of the Hemaruka profile at the Youngstown plots when irrigation was applied, together with the effects of different cultural treatments.

It was decided that small scale experimental plots would economically determine the effects of soil amendments. A field experiment was set up in which treatments of krillium, sulphur, gypsum, manure and deep cultivation were applied on different plots. The variability of the soil and the effects of soil amendments in the field were determined by grain height measurements, yield data and penetrometer evaluations. Surface and profile soil samples from the experimental plots were studied in the laboratory and this study included aggregate analyses, mechanical analyses, permeability determinations, soluble salt content and nitrogen percentages.

METHODS USED

The Field Experiments

It was necessary that experimental plots be situated on solodized solonetz soils typical of the Red Deer irrigation project area. A source of water for irrigation was also essential. The combination of these two requirements was located fifteen miles south west of Youngstown, on an abandoned farmstead (SE 1/4 - 28 - 28 - 10 W of 4). There the soil profile is a Hemaruka loam and a stock watering dam provides the necessary irrigation water. The plots were staked on an area of typical "blow out" soil with soil characteristics and vegetation as illustrated in Plate II.

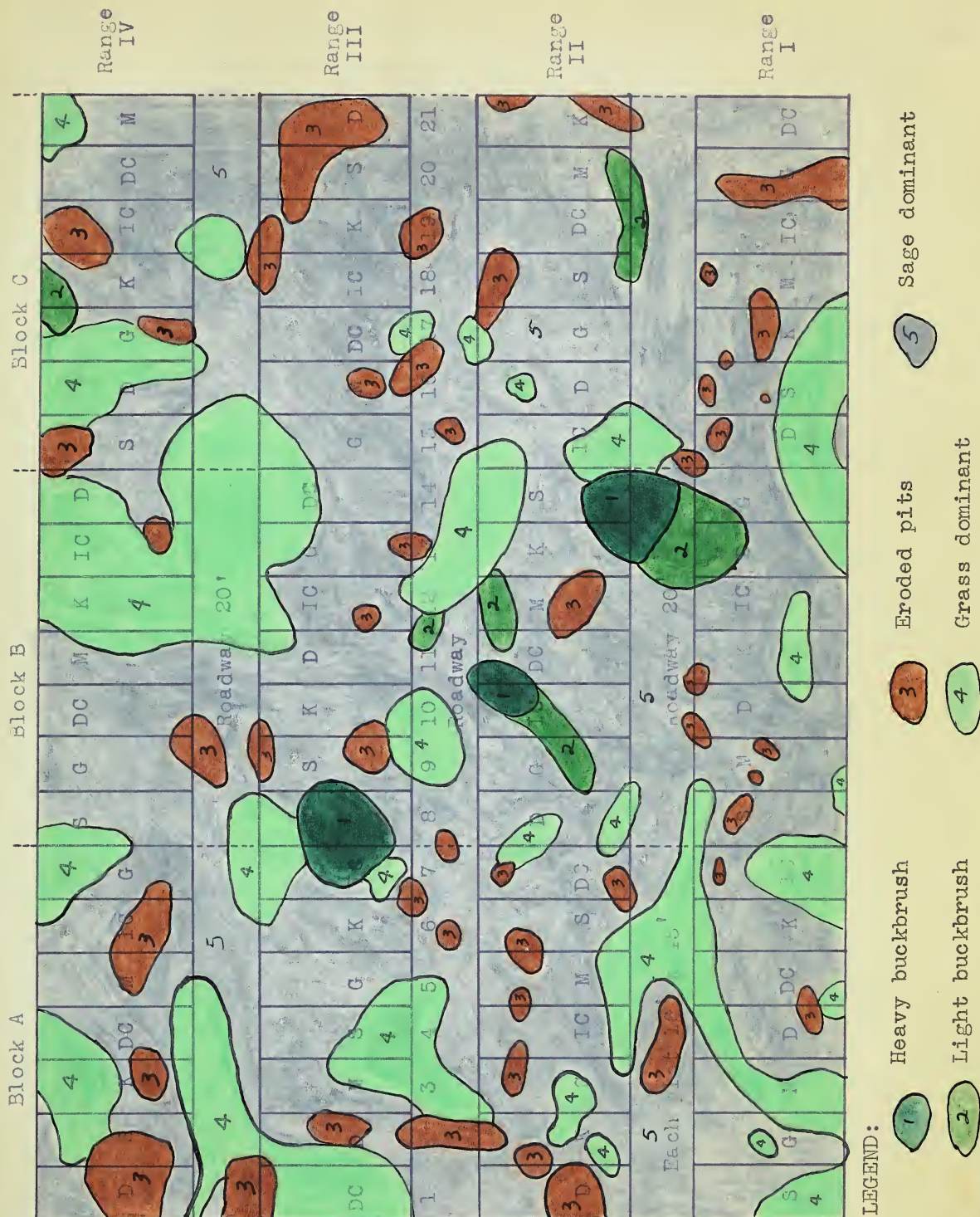
The plot design is also illustrated in Plate II. Blocks A, B and C are rotations arranged systematically in the four ranges. Seven treatments were chosen and these are randomized within each block. The rotations are as follows:

Block A sweet clover, grain

Block B continuous grain

Block C grain - sweet clover

YOUNGSTOWN PLOT VEGETATION PRIOR TO PLOWING 1952.



The 7 soil treatments selected were:

1952	Abbrev.
Krilium @ 1000 lbs. per acre on portion of plot	K ₁
Krilium @ 2000 lbs. per acre on portion of plot	K ₂
Manure @ 15 tons per acre	M
Sulphur @ 1000 lbs. per acre	S
Deep cultivation (depth 14")	DC
Irrigated check	IC
Dry check	D

1953	
Gypsum @ 1200 lbs. per acre	G
Krilium @ 2000 lbs. per acre on balance of plot	K
Manure @ 15 tons per acre	M
Sulphur (applied only in 1952)	S
Deep cultivation (depth 16")	DC
Irrigated check	IC
Dry check	D

The reactions which were theoretically expected to take place upon applying the various soil amendments are as follows:

(1) Krilium -- This synthetic polymer is a water soluble resin. In aqueous solutions it exists as a polyanion with many negative charges on the individual ions. The polyanions

The 7 sets (continued) are:

1971

- 1. 1971-1972. 1st set of 1000
- 2. 1971-1972. 2nd set of 1000
- 3. 1971-1972. 3rd set of 1000
- 4. 1971-1972. 4th set of 1000
- 5. 1971-1972. 5th set of 1000
- 6. 1971-1972. 6th set of 1000
- 7. 1971-1972. 7th set of 1000

1972

- 1. 1972-1973. 1st set of 1000
- 2. 1972-1973. 2nd set of 1000
- 3. 1972-1973. 3rd set of 1000
- 4. 1972-1973. 4th set of 1000
- 5. 1972-1973. 5th set of 1000
- 6. 1972-1973. 6th set of 1000
- 7. 1972-1973. 7th set of 1000

The following sets were also received in 1971 and 1972:

1. 1971-1972. 8th set of 1000. This set was received in 1971 and 1972.

presumably adsorb colloidal clay particles and the effect is the binding together of the clay particles by means of polymer bridges. This results in the formation of loose, spongy, clay aggregates. The treated soil mass becomes porous and friable and remarkably easy to work under certain conditions.

(2) Manure -- Dressings of farmyard manure can have very beneficial effects on soil structure. Manure increases the organic matter content of the soil, promotes biological activity and production of organic compounds that flocculate clay particles, and can consequently improve soil structure.

(3) Sulphur -- Sulphur undergoes biological oxidation in moist soil which leads to the formation of sulphuric acid. If calcium carbonate is present in the soil the sulphuric acid converts it to calcium sulphate and calcium bicarbonate which then reacts with the sodium clay. If calcium carbonate is absent, the sodium is displaced from the soil by hydrogen. The material is then changed to some degree into a "hydrogen clay" which does not have the good physical and chemical properties of a calcium clay. An excessive application of sulphur can therefore make a soil far too acid for plant growth.

(4) Gypsum -- Exchangeable sodium on the clay complex can be replaced by calcium under field conditions by adding

a soluble calcium salt such as gypsum. The result is the replacement of sodium ions by calcium ions and the consequent augmentation of replaceable calcium.

(5) A hard pan soil can sometimes be broken up by subsoiling. This action may promote root growth and may increase the water storage capacity of a soil. For these reasons it was felt desirable to include a deep cultivation treatment for comparison with the various amendments.

(6) For purposes of comparison both an irrigated and a dry check were included in the treatments.

History of the Plots

The experimental plots were laid out in May 1952 by the Research Council of Alberta and the Soils Department, University of Alberta. The Dominion Experimental Station, Lethbridge, commenced co-operative investigations on irrigation problems at this location. The writer was in charge of the University plots during the 1952 and the 1953 season. Much time was spent during the first summer doing pioneer work such as preparing the plot area, obtaining profile soil samples from each plot to a depth of four feet for future reference, building a fence to keep the range cattle out and accumulating equipment for cultural and irrigation purposes. The plot area was ploughed and cultivated and the treatments were applied.

Campana barley was sown on the plots and sweet clover was broadcasted on block A. The rill method of irrigation was used but the soil surface was rather rough and did not lend itself for any type of surface irrigation. A dugout near the the plots was kept filled with water by a pump and sprinkler line from the dam. A small portable water pump forced water through a sprinkler line to the plot roadways, and by attaching nine garden hoses on the roadway line, it was possible to irrigate nine plots at one time. Approximately six inches of water were applied to each irrigated plot during the summer months of 1952. Due to unfavourable conditions of the soil surface and poor legume catch the plots were ploughed in the fall after harvesting and left in that condition during the winter months.

The purchase of a complete line of cultural equipment favoured the preparation of the plots in 1953. The plot area was re-ploughed, many plots were levelled and the treatments, including deep cultivation, were repeated with the exception of sulphur application. The krillium @ 1000 lbs. per acre treatment was replaced by the gypsum treatment. Thatcher wheat was sown on the plots and sweet clover was again broadcast on block A. Irrigation was done in the same manner as in 1952 but with a few modifications. The dugout was not used due to seepage loss and the water was obtained directly from the dam. The use of small tin troughs with controlled openings facili-

tated the control of water. These troughs were placed at the head of alternate plots and a garden hose was placed in each trough. Approximately eight inches of water were applied on each irrigated plot during the 1953 summer months. The deep cultivation treatment was done after harvesting. During the summer land level readings were obtained for each plot.

Field Studies

Yield Determinations -- The yield for a plot was obtained by cutting a square yard sample from each of three locations, designated a, b, and c, spaced equidistant down the centre of each plot. Each sample was dried, threshed and the yield of grain calculated on an acre basis.

Height Measurements -- The crop height was classified before harvesting in 1952 and 1953 and the boundaries of the various classes were recorded on the plot plan.

Penetrometer Studies -- The hard columnar B horizon of the Hemaruka is seen in Plate III. It is expected that eventually the effects of some treatments under irrigation will be a breakdown of the B horizon. A change in soil structure would only be obvious if future evaluations of the physical condition of the soil were compared with the soil structure prior to treatment application. It was thought that penetrometer readings would indicate such

...the method of ... these ...
...the need of ... and ...
...each ...
...on each ...
...these ...
...the ...

Field ...

Field ... -- The ...
...obtained ...
...locations, ...
...the ...
...the ...

Field ... -- The ...
...these ...
...the ...

Field ... -- The ...
...of the ...
...essentially ...
...will be ...
...circumstances ...
...physical ...
...the ...
...should ...

PLATE III

THE HEMARUKA PROFILE



structural changes. The writer designed a self recording soil penetrometer in 1953 for the particular conditions at the Youngstown plots. This self recording soil penetrometer, as shown in Plate IV and Plate V has the following features:

1. The machine is light in weight and convenient to transport.
2. The graph carriage moves, relative to the ground surface at a constant rate which is controlled by the operator and this rate of movement can be replicated by any operator.
3. A self filling recording pen records the resistance to probe penetration in the soil. Movement of the pen in the "X" direction indicates the depth of probe penetration. The resistance encountered by the probe as it is forced into the soil is denoted by the movement of the pen in the "Y" direction. This results from and is proportional to the compression of two calibrated springs, and the compression of these springs is in turn proportional to penetration resistance.
4. After the recording pen on the carriage draws the resistance vs. depth line on the paper, the pen draws a "Y" axis when the graph carriage is pulled up, then as the probe is pulled from the ground, draws an "X" axis returning to its starting position,

structural changes, the water system is well maintained and functioning in 1953. The water supply is sufficient for the population of the city. The water supply is sufficient for the population of the city. The water supply is sufficient for the population of the city.

1. The water supply is sufficient for the population of the city. The water supply is sufficient for the population of the city. The water supply is sufficient for the population of the city.

2. The water supply is sufficient for the population of the city. The water supply is sufficient for the population of the city. The water supply is sufficient for the population of the city.

3. The water supply is sufficient for the population of the city. The water supply is sufficient for the population of the city. The water supply is sufficient for the population of the city.

4. The water supply is sufficient for the population of the city. The water supply is sufficient for the population of the city. The water supply is sufficient for the population of the city.

PLATE IV

THE SELF RECORDING SOIL PENETROMETER

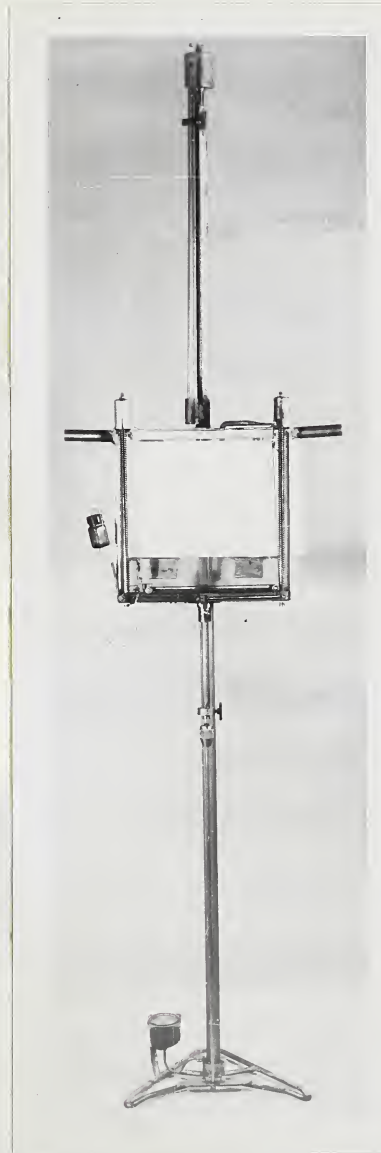


PLATE V

THE SELF RECORDING SOIL PENETROMETER
CLOSE UP OF GRAPH CARRIAGE

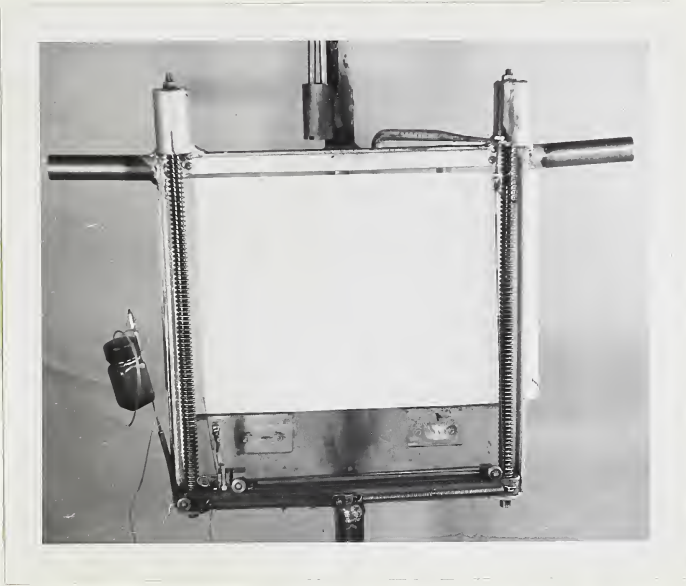
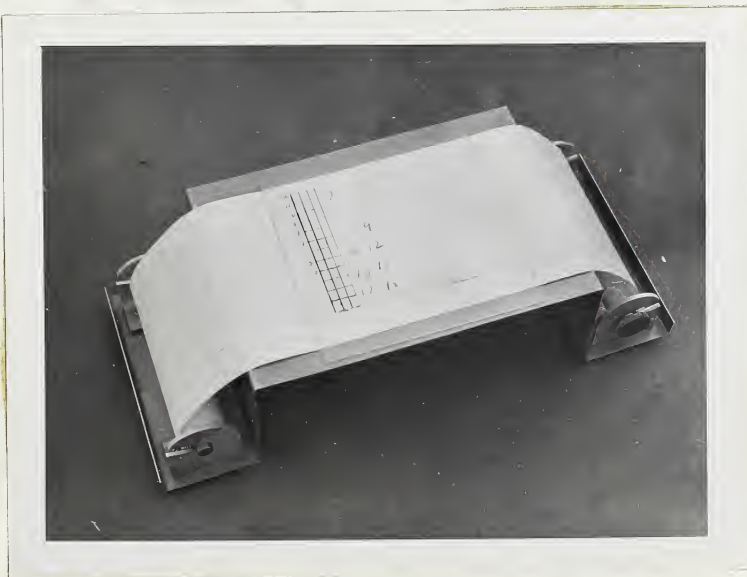


PLATE VI

THE MASTER GRAPH AND TABLE FOR PENETROMETER GRAPH ROLL



5. A blank paper roll is used instead of individual sheets and the number of consecutive graphs that can be drawn is limited only by the size of the roll. Paper rolls are simply and conveniently filed.
6. Replications are rapid and simple. No adjustments are necessary for replications as the pen returns to its starting position when the probe is lifted out of the soil. The probe is pushed into the soil, pulled out, moved to a new location and the process repeated. Where no extension to the probe is called for less than half a minute is required for each graph.
7. The penetrometer is designed to take readings to varying maximum depths of from eight inches to eight feet, the limit being determined only by soil consolidation.
8. Penetrometer readings can be taken in the field under windy conditions without affecting the efficiency of the machine or the operator.
9. Probes of different sizes and shapes can be attached to the probe stem to adapt probe resistance to spring tension.

Penetrometer readings of the Youngstown plots were first taken in June 1953. A minimum of three replications was taken at each of three locations, designated a, b, and c and coinciding with yield location, in each plot. The penetrometer settings were as follows:

probe diameter	-	5/16 inch
probe stem diameter	-	1/4 inch
spring tension	-	3 lbs./inch/spring
downward travel of graph carriage	-	1 ft./8 sec.

A stop collar was adjusted on the main stem so that the springs could be compressed only six inches. It took the writer two days to take penetrometer readings in the 84 plots, a minimum of 756 readings. These readings were repeated after harvesting, using the same technique.

A method of evaluating penetrometer graphs for practical application was necessary. Consequently the small table shown in Plate VI was constructed so that graph rolls could be conveniently examined. A master graph with graduated "X" and "Y" axes corresponding to the resistance and depth of probe penetration was drawn on a lucite sheet. To evaluate the graphs, the master graph was placed on the field graph, superimposing X and Y axes, and the desired information obtained from a study of the average curve, which was determined by visual estimation.

Information obtained from penetrometer graphs include the resistance of the first, second and third inch of surface soil to probe penetration, and the depth of isoprobes. Surface soil resistance was determined by allocating resistance units to the "Y" axis and then evaluating the resistance in each case. The term "isoprobes" designates points in the profile with equal resistance. The depth of isoprobes was determined from the graphs as the depths at which the resistance of probe penetration compressed the springs six inches. These isoprobes were plotted on graphs showing the profile of the plots. A profile graph was made of the plots in which the surface soil was plotted to scale from level readings and isoprobes were plotted to the depth below surface. This profile study was made for locations a, b and c of each range, and included isoprobes from June and September readings (1953). A three dimensional plan of the Youngstown plots was also made to scale using level readings and June 1953 isoprobes.

Laboratory Studies

Soil samples used for laboratory studies were obtained in the following manner:

1. Undisturbed soil core samples, using the Uhland core sampler and Uhland's technique, were obtained

from the plots after harvesting in 1952. Permeability and porosity determinations were made from these samples.

2. Profile soil samples of certain plots were taken in June, 1953, at six inch intervals to a depth of four feet with a King tube. The soluble salt content and mechanical analysis of these samples were determined.
3. A composite soil sample from each plot was taken at an average depth of three inches after harvesting in 1953. Laboratory study of each plot sample included aggregate analysis and mechanical analysis. Nitrogen percentages were determined on a few of the soils darkest in color and a few of the lightest in color to determine the extremes of N content.

Aggregate Analysis

Yoder's technique (65) for aggregate analysis was followed except for modification in the pre-treatment of the sample. The composite soil sample was air dried, then passed through a 1/2" mesh sieve. Larger clods were crushed by a heavy roller on tracks 1/4" high thus eliminating unnecessary disruption of aggregation and were re-sieved through the 1/2" mesh sieve. A 50 gram sample was used and wetting of the

2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213 2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226 2227 2228 2229 2230 2231 2232 2233 2234 2235 2236 2237 2238 2239 2240 2241 2242 2243 2244 2245 2246 2247 2248 2249 2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 2278 2279 2280 2281 2282 2283 2284 2285 2286 2287 2288 2289 2290 2291 2292 2293 2294 2295 2296 2297 2298 2299 2300 2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313 2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326 2327 2328 2329 2330 2331 2332 2333 2334 2335 2336 2337 2338 2339 2340 2341 2342 2343 2344 2345 2346 2347 2348 2349 2350 2351 2352 2353 2354 2355 2356 2357 2358 2359 2360 2361 2362 2363 2364 2365 2366 2367 2368 2369 2370 2371 2372 2373 2374 2375 2376 2377 2378 2379 2380 2381 2382 2383 2384 2385 2386 2387 2388 2389 2390 2391 2392 2393 2394 2395 2396 2397 2398 2399 2400 2401 2402 2403 2404 2405 2406 2407 2408 2409 2410 2411 2412 2413 2414 2415 2416 2417 2418 2419 2420 2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2432 2433 2434 2435 2436 2437 2438 2439 2440 2441 2442 2443 2444 2445 2446 2447 2448 2449 2450 2451 2452 2453 2454 2455 2456 2457 2458 2459 2460 2461 2462 2463 2464 2465 2466 2467 2468 2469 2470 2471 2472 2473 2474 2475 2476 2477 2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659 2660 2661 2662 2663 2664 2665 2666 2667 2668 2669 2670 2671 2672 2673 2674 2675 2676 2677 2678 2679 2680 2681 2682 2683 2684 2685 2686 2687 2688 2689 2690 2691 2692 2693 2694 2695 2696 2697 2698 2699 2700 2701 2702 2703 2704 2705 2706 2707 2708 2709 2710 2711 2712 2713 2714 2715 2716 2717 2718 2719 2720 2721 2722 2723 2724 2725 2726 2727 2728 2729 2730 2731 2732 2733 2734 2735 2736 2737 2738 2739 2740 2741 2742 2743 2744 2745 2746 2747 2748 2749 2750 2751 2752 2753 2754 2755 2756 2757 2758 2759 2760 2761 2762 2763 2764 2765 2766 2767 2768 2769 2770 2771 2772 2773 2774 2775 2776 2777 2778 2779 2780 2781 2782 2783 2784 2785 2786 2787 2788 2789 2790 2791 2792 2793 2794 2795 2796 2797 2798 2799 2800 2801 2802 2803 2804 2805 2806 2807 2808 2809 2810 2811 2812 2813 2814 2815 2816 2817 2818

sample was done under vacuum. The apparatus for vacuum wetting of the sample is shown on Plate VII and the wet-sieving equipment is shown on Plate VIII. Specifications regarding sieve size and machine operation are shown in Table I in comparison with figures used by other workers.

Mechanical Analysis

The revised procedure of the pipette method as suggested by Toogood and Peters (56) was used for mechanical analysis of soil samples.

Permeability and Porosity Studies

Permeability and porosity studies were conducted according to procedures used by Uhland and O'Neal (58).

Soluble Salts

Conductivity measurements are expressed in millimhos/cm² on a soil to water ratio of 1:5, using a standardized conductivity cell in conjunction with a Wheatstone Bridge. Standard methods currently used by the Soils Department, University of Alberta, were used to determine the soluble salts on the 1:5 extract.

...has been used, ...
...of the ...
...to ...
...is ...
...in ...

Geometrical Analysis

The ...
...by ...
...is ...

Experimental and Theoretical Results

...and ...
...is ...

Conclusions

...
...
...
...
...
...
...

PLATE VII

APPARATUS FOR VACUUM WETTING OF THE SAMPLE

FOR AGGREGATE ANALYSIS

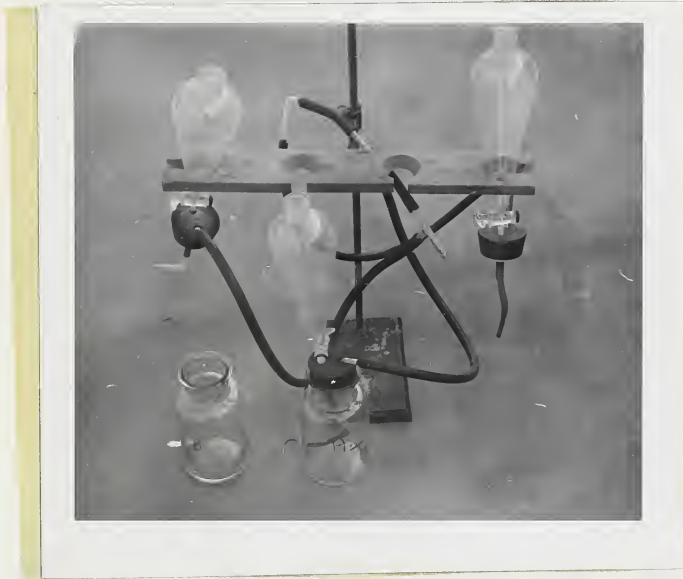


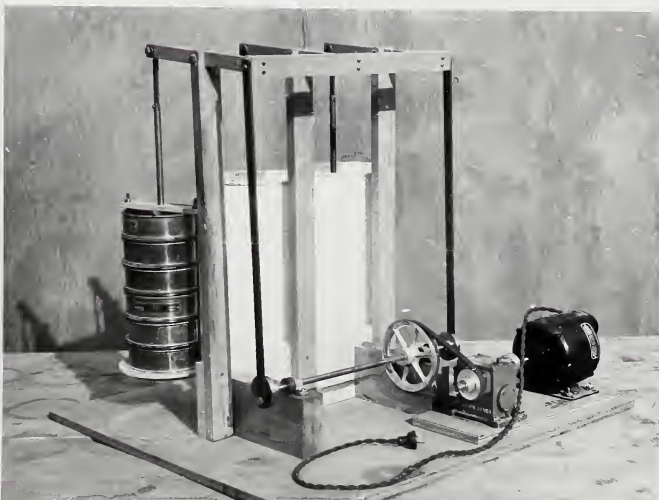
PLATE VIII

WET SIEVING EQUIPMENT USED FOR
AGGREGATE ANALYSES

Front view



Rear view



The techniques used for salt determinations were:

- | | |
|------------------|--|
| Na | by flame photometer. |
| Ca and Mg. | Ca was determined by titrations with
.01 versene using murexide as indicator
Ca plus Mg was determined by titrations
with .01 versene using erichrome black
T indicator. Mg was determined by
difference. |
| SO ₄ | by turbidimetric method following mimeo-
graph method by Schroer and Bentley
as used in the Soils lab. |
| HCO ₃ | by titrations with .02M H ₂ SO ₄ using
methyl orange indicator. |
| CO ₃ | by titrations with .02N H ₂ SO ₄ using
phenolphthalein indicator. |
| Cl | by titrations with AgNO ₃ using potassium
chromate indicator. |

Nitrogen Determination

Nitrogen was determined by the modified Kjeldahl method using selenium as described by the association of official agricultural chemists.

RESULTS

Field Results

The height measurements made on barley, 1952, and wheat, 1953, are diagrammatically illustrated in Plate IX and Plate X. Note the extreme variability which in both years largely masked the effects of treatments. Note too the better growth in 1953.

The average yield of grain for each treatment is graphically presented in Plate XI. Table 2 and 3 give the data in full for the two years as well as the analysis of variance of the wheat and barley yields, the average yields and the L.S.D. Statistical analysis showed no significant differences due to treatments in 1952 while in 1953 some differences were obtained. Table 4 lists the wheat yield in grams for each square yard sample in a representative portion of the plots and the data show the large amount of variation not only between plots but also within the plots. With such variations it is not surprising that few significant differences were revealed by statistical analysis. Such variation is also indicative of the extremely variable nature of the soil.

The depth of penetrometer isoprobes for June and September, 1953 in each plot is illustrated in the profile

diagrams of Plate XVI, XVII, XVIII and XIX in the Appendix. Note that, in general, the June isoprobes were much deeper than the September isoprobes. This may be accounted for by the fact that heavy rains lead to a high soil moisture content in June. By September the soil had dried out and the isoprobes were closer to the surface. In a few cases the September isoprobes were deeper than the June indicating a softening of soil structure permitting deeper probe penetration. The large variability in the soil from plot to plot is again evident from a study of the profile diagrams.

The data for isoprobe measurements are summarized in Table 5, each figure representing an average of 108 measurements. The June and September isoprobe data are given in full in Table 6 and 7 as well as the analysis of variance and treatment averages. The June data show no significant differences on statistical analysis, but show a greater average depth of isoprobes than the September readings. The September data (see Table 5) show krillium, gypsum, and sulphur as having caused a significant difference over the remaining treatments. These treatments apparently lowered the isoprobes, indicating a beneficial effect on the soil.

A three dimensional model of the plots showing relief and June isoprobes was photographed and is shown in Plate XII. This model was of value in studying effects of

native vegetation, topography and profile and in relating these to crop responses.

The hardness of the surface soil shown by the resistance as measured by penetrometer probe penetration of the first, second, and third inch for each treatment is graphically presented in Plate XIII. Also shown in the mean weight diameter of soil aggregates for each treatment. The resistance factor represents the average of a minimum of 108 penetrometer readings while the mean weight diameter represents the average of 12 replicates. The data and the analysis of variance for the resistance factor and aggregate analysis are given in Table 8, 9, 10 and 11. They show krilium as the only effective treatment for soil aggregation as measured by aggregate analysis, while krilium, gypsum and sulphur were found to cause significant effects when measured by the resistance factor.

Laboratory Results

The results of mechanical analysis of surface soil from each of the 84 plots are pinpointed on the soil textural triangle in Plate XIV. Note the variability in texture in this two acre area.

Aggregate analysis studies done in the laboratory have already been referred to in connection with resistance

factor measurements.

Permeability rates and porosity as measured by the Uhland soil core technique and mechanical analysis are used in Plate XV to illustrate the wide differences in physical characteristics between a selected eroded pit profile in Range III and a permeable profile in Range IV. Note the different permeability rates in the two profiles and also the variations in the mechanical analysis of the eroded pit profile.

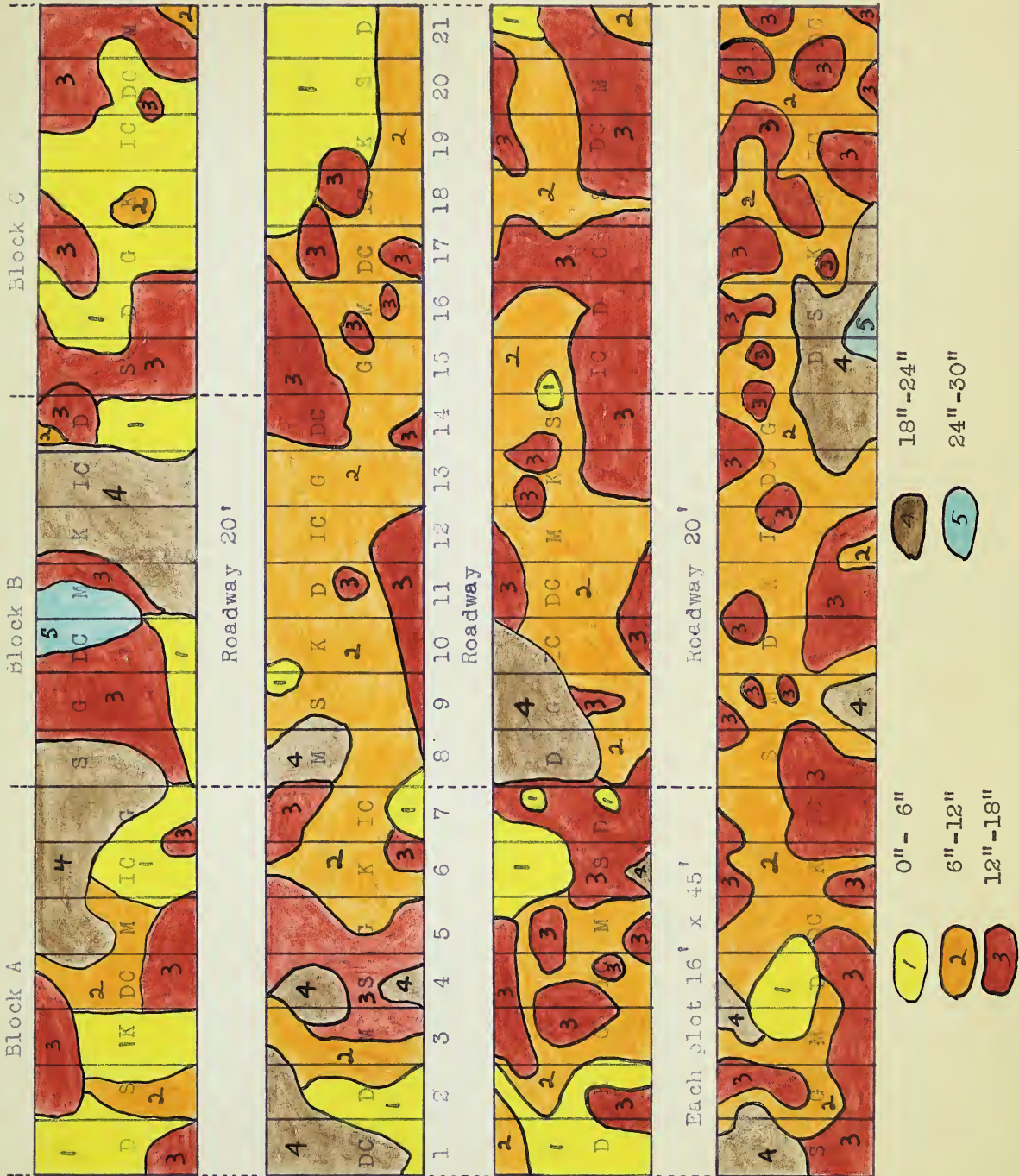
The variations in soluble salts of several profile samples is indicated in Table 12. In general the sodium content is higher than the calcium or magnesium in the soil profiles while calcium tends to increase with increasing depth. The approximate limits of salinity according to the conductivity scale on a 1:5 soil to water ratio used by Alberta Soil Survey are as follows:

<u>Conductivity</u>	<u>Soluble salts-percentage</u>	<u>Effects</u>
0 - .4	0 - .15	No evidence of salt injury.
.4 - .8	.15 - .35	Sensitive crops do not thrive. Tolerant crops may do well.
.8 - 1.5	.35 - .65	Crop growth restricted. Fields usually poor.
1.5 -	Above .65	Only a few species survive..

In general, Table 12 shows a low conductivity for the surface six inches of soil, but conductivity increases rapidly with increasing depth in most cases and reaches a salinity which might be toxic to plants.

Variations in soil fertility between plots is estimated by determining the nitrogen content of several surface soil samples (see Table 13). The data indicate the low level of organic matter present, characteristic of the brown soil zone.

September, 1952.



HEIGHT MEASUREMENTS OF WHEAT AT YOUNGSTOWN PLOTS

September, 1953.

Range
IV

Range
III

Range
II

Range
I

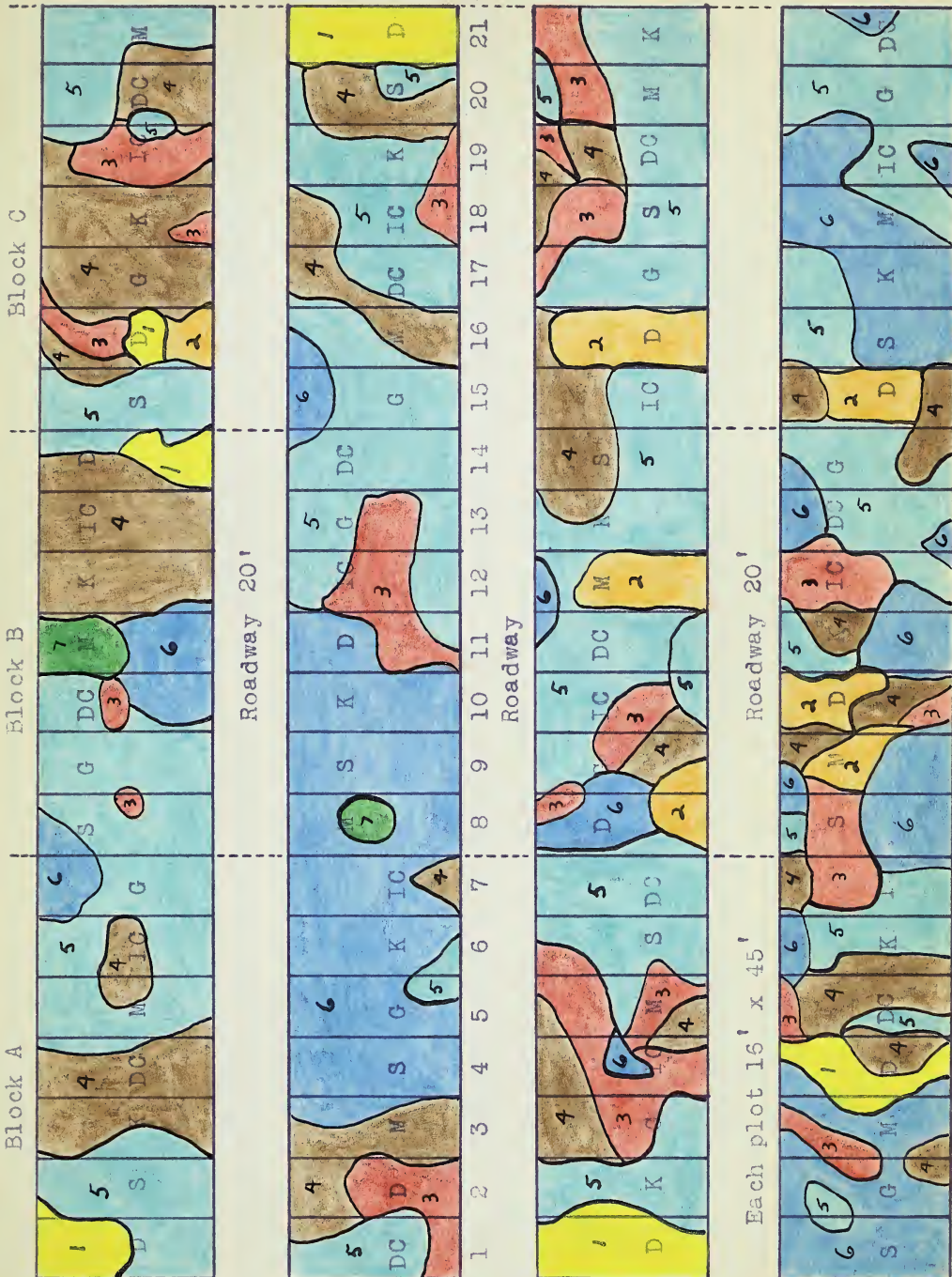


PLATE XI

YOUNGSTOWN PLOT YIELDS

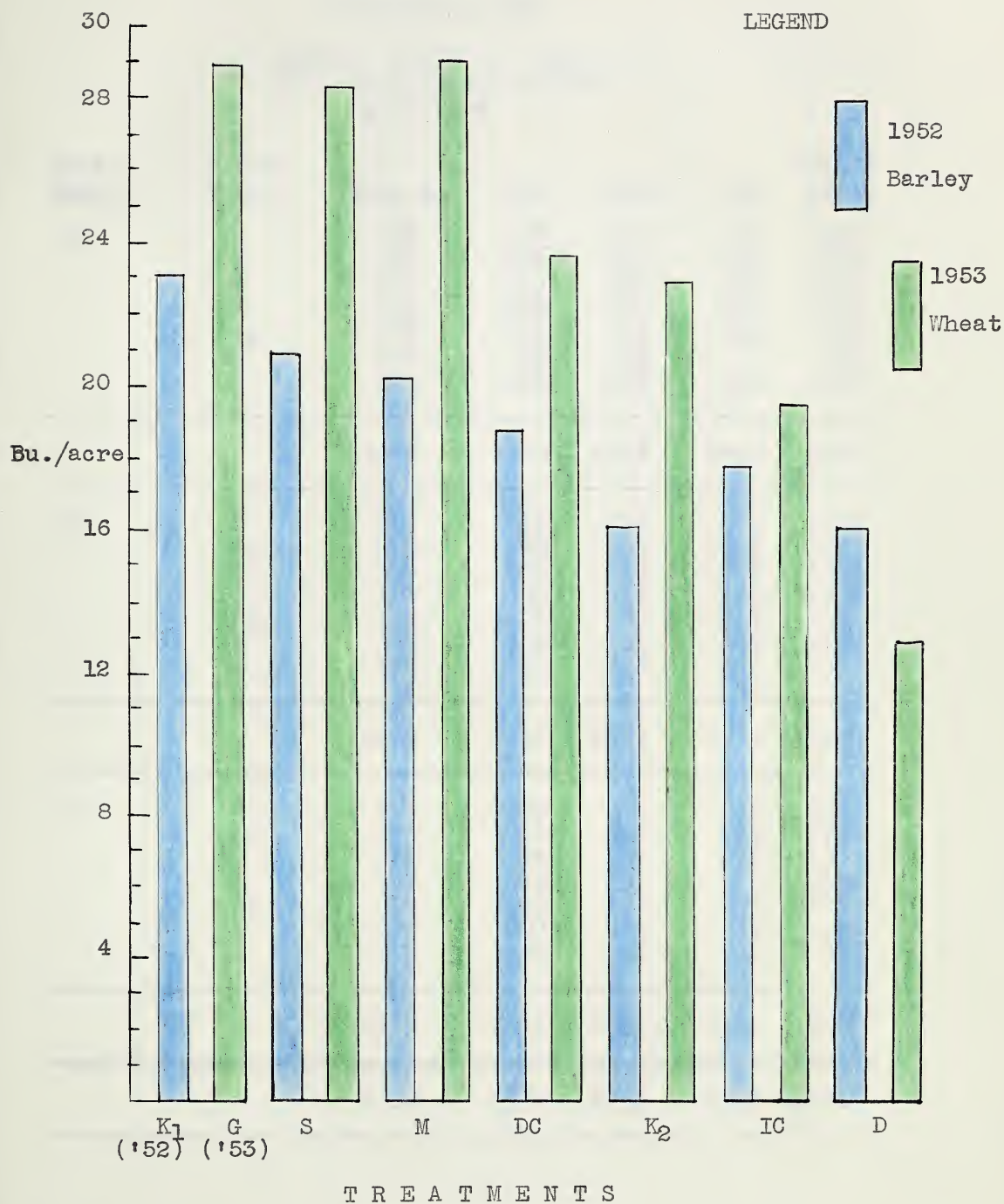


TABLE 2

YOUNGSTOWN PLOTS

BARLEY YIELD - 1952
AND ANALYSIS OF VARIANCE
(gms./plot)

<u>Rotation</u>	<u>Treatment</u>	<u>Rep. I.</u>	<u>II.</u>	<u>III.</u>	<u>IV.</u>	<u>Rot. x Trt.</u>
A	S	596	297	695	262	1850
	K	304	254	476	492	1526
	DC	223	317	668	129	1337
	M	339	284	306	290	1219
	K ₂	208	437	42	180	867
	D	111	24	233	1	369
	IC	205	582	298	275	1360
		1986	2195	2718	1629	8528
B	S	317	236	285	662	1500
	K ₁	316	708	285	327	1636
	DC	384	302	464	526	1676
	M	145	102	689	854	1790
	K ₂	487	176	254	474	1391
	D	382	610	685	242	1919
	IC	458	264	278	570	1570
		2489	2398	2940	3655	11482
C	S	604	305	4	237	1150
	K ₁	175	711	528	359	1773
	DC	310	354	154	226	1044
	M	484	329	191	432	1436
	K ₂	394	530	161	134	1219
	D	308	493	2	383	1186
	IC	578	220	92	10	900
		2853	2942	1132	1781	8708
		7328	7535	6790	7065	28718

TABLE 2 (cont'd.)

ANALYSIS OF VARIANCE OF BARLEY YIELDS

<u>Treatments</u> (grams)		<u>Average</u>		<u>bu./acre</u>
S	4500	S	375	22.3
K ₁	4935	K ₁	411	24.4
DC ₁	4057	DC	338	24.1
M	4445	M	370	21.9
K ₂	3477	K ₂	290	17.2
D	3474	D	290	17.2
IC	3830	IC	319	18.9
<hr/>				
28718				

Source of Variation	SS	DF	MS	F	5%	1%
Reps.	14,917	3	4972	.055		
Rotation	195,876	2	97938	1.08		
Error (1)	542,483	6	90413			
Trts.	152,580	6	25430	.76	2.29	3.18
Rot.x TRTs.	359,579	12	29965	.90		
Error (2)	1,794,386	54				
T O T A L	3,059,821	83				

No LSD.

TABLE 3

YOUNGSTOWN PLOTS

WHEAT YIELD - 1953
AND ANALYSIS OF VARIANCE
(gms/plot)

<u>Rotation</u>	<u>Treatments</u>	<u>Rep. I.</u>	<u>II.</u>	<u>III.</u>	<u>IV.</u>	<u>Rot. x Trt.</u>
A	S	503	314	662	477	1956
	K	419	290	444	282	1435
	G	456	347	467	562	1832
	M	563	197	423	446	1629
	DC	284	287	335	308	1214
	IC	387	310	415	476	1588
	D	120	14	126	192	452
		2732	1759	2872	2743	10106
B	S	461	331	513	622	1927
	K	524	464	484	93	1565
	G	465	558	436	503	1962
	M	256	227	851	807	2141
	DC	516	351	569	470	1906
	IC	176	288	283	106	853
	D	259	421	496	294	1470
		2657	2640	3632	2895	11824
C	S	484	352	355	615	1806
	K	483	365	447	332	1627
	G	472	623	567	471	2133
	M	523	355	548	638	2064
	DC	461	467	257	459	1644
	IC	513	477	327	157	1474
	D	165	194	1	289	649
		3101	2833	2502	2961	11397
		8490	7232	9006	8599	33327

TABLE 3 (cont'd.)

ANALYSIS OF VARIANCE OF WHEAT YIELDS

<u>Treatments</u>		<u>Average</u>		
		(grams)		bu./acre
S	5689	S	474	28.1
K	4627	K	385	22.8
G	5927	G	494	29.3
M	5834	M	486	28.8
DC	4764	DC	397	23.6
IC	3915	IC	326	19.3
D	2571	D	214	12.7
<hr/>				
	33327			

Source of Variation	SS	DF	MS	F
Reps.	83834	3	27945	1.11
Rotations	57149	2	28574	1.14
Error (1)	151051	6	25175	
Trts.	741821	6	123637	7.83 ^{**}
Rot. x Trts.	285357	12	23779	1.51
Error (2)	852387	54	15785	
T O T A L	2171599	83		

LSD at 5% level of significance = 102.6 g. = 6.1 bu./ac.

LSD at 1% level of significance = 115.5 g. = 6.9 bu./ac.

TABLE 4

WHEAT YIELDS IN GRAMS OF EACH SQUARE YARD SAMPLE
IN PART OF THE YOUNGSTOWN PLOTS, 1953.

Range I.						Range II.				
Plot	Tre- at- ment	a.	b.	c.	Total	Tre- at- ment	a.	b.	c.	Total
1	S	120	178	205	503	D	0	0	14	14
2	G	156	174	126	456	K	50	138	102	290
3	M	151	269	143	563	G	146	69	132	347
4	D	99	0	21	120	IC	56	150	104	310
5	DC	149	62	73	284	M	92	80	25	197
6	K	148	107	164	419	S	143	130	41	314
7	IC	144	187	56	387	DC	107	93	87	287

Range III.						Range IV.				
15	G	187	204	176	567	S	268	212	135	615
16	M	200	168	180	548	D	9	104	176	289
17	DC	80	106	71	257	G	208	107	156	471
18	IC	121	110	96	327	K	118	130	84	332
19	K	172	110	165	447	IC	25	68	64	157
20	S	153	92	110	355	DC	119	136	204	459
21	D	0	0	1	1	M	203	185	250	638

TABLE 5

YOUNGSTOWN PLOTS
THE AVERAGE DEPTH OF ISOPROBES
1953

<u>Treatment</u>	<u>Depth (inches)</u>	
	<u>June</u>	<u>September</u>
Krilium	20.2	10.7
Gypsum	19.5	12.8
Sulphur	21.7	10.0
Manure	19.8	5.8
Deep Cultivation	21.1	5.6
Irrigated Check	16.0	6.8
Dry Check	19.2	7.8

TABLE 6

PENETROMETER DATA FOR YOUNGSTOWN PLOTS

DEPTH OF ISOPROBES (INCHES)

June 1953.

AND ANALYSIS OF VARIANCE

<u>Rotation</u>	<u>Treatments</u>	<u>Rep. I.</u>	<u>II.</u>	<u>III.</u>	<u>IV.</u>	<u>Rot. x Trt.</u>
A	K	8	15	30	27	80
	G	18	17	14	28	77
	S	33	19	25	32	109
	M	25	15	11	18	69
	DC	19	29	51	19	118
	IC	9	19	12	17	57
	D	16	10	18	20	64
		128	124	161	161	574
B	K	9	12	33	42	96
	G	13	19	13	9	54
	S	19	26	28	21	94
	M	18	21	30	42	111
	DC	15	19	17	24	75
	IC	10	9	18	33	70
	D	23	38	27	15	103
		107	144	166	186	603
C	K	28	20	9	9	66
	G	26	23	21	33	103
	S	12	12	18	16	58
	M	13	10	11	23	57
	DC	14	14	22	11	61
	IC	25	19	12	13	69
	D	15	31	7	13	66
		133	129	100	118	480
		368	397	427	465	1657

Table 1

Table 1. Summary of the results of the analysis of variance for the effect of the treatment on the response of the subjects.

Table 1. Summary of the results of the analysis of variance for the effect of the treatment on the response of the subjects.

Table 1. Summary of the results of the analysis of variance for the effect of the treatment on the response of the subjects.

Table 1. Summary of the results of the analysis of variance for the effect of the treatment on the response of the subjects.

Source of Variation	Sum of Squares	Mean Square	F	df	Significance
Treatment	10.00	10.00	1.00	1	0.33
Block	10.00	10.00	1.00	1	0.33
Error	10.00	10.00	1.00	1	0.33
Total	30.00			3	
Treatment	10.00	10.00	1.00	1	0.33
Block	10.00	10.00	1.00	1	0.33
Error	10.00	10.00	1.00	1	0.33
Total	30.00			3	
Treatment	10.00	10.00	1.00	1	0.33
Block	10.00	10.00	1.00	1	0.33
Error	10.00	10.00	1.00	1	0.33
Total	30.00			3	
Treatment	10.00	10.00	1.00	1	0.33
Block	10.00	10.00	1.00	1	0.33
Error	10.00	10.00	1.00	1	0.33
Total	30.00			3	

TABLE 6 (cont'd.)

ANALYSIS OF VARIANCE FOR JUNE ISOPROBES

<u>Treatment</u>		<u>Average</u>	
K	242	K	20.1
G	234	G	19.5
S	261	S	21.7
M	237	M	19.8
DC	254	DC	21.1
IC	196	IC	16.3
D	233	D	19.4
<hr/>			
1657			

Source of Variation	SS	DF	MS	F	5%	1%
Reps.	247	3	82.3	.47		
Rotation	296	2	148	.84		
Error (1)	1056	6	176			
Trts.	217	6	36.2	.64	2.29	3.18
Rot. x Trt.	1570	12	13.1	.23		
Error (2)	3041	54	56.3			
	6427	83				

Treatments not significant - No LSD.

TABLE 7

PENETROMETER DATA FOR YOUNGSTOWN PLOTS

DEPTH OF ISOPROBES (INCHES)
AND ANALYSIS OF VARIANCE
September 1953.

<u>Retar-</u> <u>tion</u>	<u>Treat-</u> <u>ments</u>	<u>Rep. I.</u>	<u>II.</u>	<u>III.</u>	<u>IV.</u>	<u>Rot. x</u> <u>Trt.</u>
A	K	9	3	9	7	28
	G	8	9	14	12	43
	S	9	4	17	14	44
	M	2	1	6	2	11
	DC	1	2	5	3	11
	IC	6	3	5	6	20
	D	5	1	1	9	26
		40	23	67	53	183
B	K	14	15	12	19	60
	G	11	8	10	12	41
	S	12	8	13	15	48
	M	4	3	10	4	21
	DC	7	7	10	9	33
	IC	8	7	3	18	36
	D	8	14	11	7	40
		64	62	69	84	279
C	K	16	8	6	12	42
	G	13	15	12	22	62
	S	15	7	5	11	38
	M	12	9	5	11	37
	DC	4	4	3	8	19
	IC	17	4	3	2	26
	D	11	6	2	9	28
		88	53	36	75	252
		192	138	172	212	714

TABLE 7 (cont'd.)

ANALYSIS OF VARIANCE FOR SEPTEMBER ISOPROBES

<u>Treatment</u>		<u>Average</u>	
K	130	K	10.7
G	146	G	12.8
S	130	S	10.0
M	69	M	5.8
DC	63	DC	5.6
IC	82	IC	6.8
D	94	D	7.8
<hr/>			
714			

Source of Variation	SS	DF	MS	F	5%	1%
Reps.	142	3	47.3	1.02		
Rotation	175	2	87.5	1.88		
Error (1)	279	6	46.5			
Trts.	548	6	91.3	10.26**	2.29	3.18
Rot. x Trts.	243	12	20.3	2.28		
Error (2)	480	54	8.9			
TOTAL	1867	83				

LSD at 5% level of significance = 2.44
 LSD at 1% level of significance = 3.29

1990		1991	
1.1	1.1	1.1	1.1
1.2	1.2	1.2	1.2
1.3	1.3	1.3	1.3
1.4	1.4	1.4	1.4
1.5	1.5	1.5	1.5
1.6	1.6	1.6	1.6
1.7	1.7	1.7	1.7
1.8	1.8	1.8	1.8
1.9	1.9	1.9	1.9
1.10	1.10	1.10	1.10
1.11	1.11	1.11	1.11
1.12	1.12	1.12	1.12
1.13	1.13	1.13	1.13
1.14	1.14	1.14	1.14
1.15	1.15	1.15	1.15
1.16	1.16	1.16	1.16
1.17	1.17	1.17	1.17
1.18	1.18	1.18	1.18
1.19	1.19	1.19	1.19
1.20	1.20	1.20	1.20
1.21	1.21	1.21	1.21
1.22	1.22	1.22	1.22
1.23	1.23	1.23	1.23
1.24	1.24	1.24	1.24
1.25	1.25	1.25	1.25
1.26	1.26	1.26	1.26
1.27	1.27	1.27	1.27
1.28	1.28	1.28	1.28
1.29	1.29	1.29	1.29
1.30	1.30	1.30	1.30
1.31	1.31	1.31	1.31
1.32	1.32	1.32	1.32
1.33	1.33	1.33	1.33
1.34	1.34	1.34	1.34
1.35	1.35	1.35	1.35
1.36	1.36	1.36	1.36
1.37	1.37	1.37	1.37
1.38	1.38	1.38	1.38
1.39	1.39	1.39	1.39
1.40	1.40	1.40	1.40
1.41	1.41	1.41	1.41
1.42	1.42	1.42	1.42
1.43	1.43	1.43	1.43
1.44	1.44	1.44	1.44
1.45	1.45	1.45	1.45
1.46	1.46	1.46	1.46
1.47	1.47	1.47	1.47
1.48	1.48	1.48	1.48
1.49	1.49	1.49	1.49
1.50	1.50	1.50	1.50
1.51	1.51	1.51	1.51
1.52	1.52	1.52	1.52
1.53	1.53	1.53	1.53
1.54	1.54	1.54	1.54
1.55	1.55	1.55	1.55
1.56	1.56	1.56	1.56
1.57	1.57	1.57	1.57
1.58	1.58	1.58	1.58
1.59	1.59	1.59	1.59
1.60	1.60	1.60	1.60
1.61	1.61	1.61	1.61
1.62	1.62	1.62	1.62
1.63	1.63	1.63	1.63
1.64	1.64	1.64	1.64
1.65	1.65	1.65	1.65
1.66	1.66	1.66	1.66
1.67	1.67	1.67	1.67
1.68	1.68	1.68	1.68
1.69	1.69	1.69	1.69
1.70	1.70	1.70	1.70
1.71	1.71	1.71	1.71
1.72	1.72	1.72	1.72
1.73	1.73	1.73	1.73
1.74	1.74	1.74	1.74
1.75	1.75	1.75	1.75
1.76	1.76	1.76	1.76
1.77	1.77	1.77	1.77
1.78	1.78	1.78	1.78
1.79	1.79	1.79	1.79
1.80	1.80	1.80	1.80
1.81	1.81	1.81	1.81
1.82	1.82	1.82	1.82
1.83	1.83	1.83	1.83
1.84	1.84	1.84	1.84
1.85	1.85	1.85	1.85
1.86	1.86	1.86	1.86
1.87	1.87	1.87	1.87
1.88	1.88	1.88	1.88
1.89	1.89	1.89	1.89
1.90	1.90	1.90	1.90
1.91	1.91	1.91	1.91
1.92	1.92	1.92	1.92
1.93	1.93	1.93	1.93
1.94	1.94	1.94	1.94
1.95	1.95	1.95	1.95
1.96	1.96	1.96	1.96
1.97	1.97	1.97	1.97
1.98	1.98	1.98	1.98
1.99	1.99	1.99	1.99
2.00	2.00	2.00	2.00

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2433	2434	2435	2436	2437	2438	2439	2440	2441	2442	2443	2444	2445	2446	2447	2448	2449	2450	2451	2452	2453	2454	2455	2456	2457	2458	2459	2460	2461	2462	2463	2464	2465	2466	2467	2468	2469	2470	2471	2472	2473	2474	2475	2476	2477	2478	2479	2480	2481	2482	2483	2484	2485	2486	2487	2488	2489	2490	2491	2492	2493	2494	2495	2496	2497	2498	2499	2500	2501	2502	2503	2504	2505	2506	2507	2508	2509	2510	2511	2512	2513	2514	2515	2516	2517	2518	2519	2520	2521	2522	2523	2524	2525	2526	2527	2528	2529	2530	2531	2532	2533	2534	2535	2536	2537	2538	2539	2540	2541	2542	2543	2544	2545	2546	2547	2548	2549	2550	2551	2552	2553	2554	2555	2556	2557	2558	2559	2560	2561	2562	2563	2564	2565	2566	2567	2568	2569	2570	2571	2572	2573	2574	2575	2576	2577	2578	2579	2580	2581	2582	2583	2584	2585	2586	2587	2588	2589	2590	2591	2592	2593	2594	2595	2596	2597	2598	2599	2600	2601	2602	2603	2604	2605	2606	2607	2608	2609	2610	2611	2612	2613	2614	2615	2616	2617	2618	2619	2620	2621	2622	2623	2624	2625	2626	2627	2628	2629	2630	2631	2632	2633	2634	2635	2636	2637	2638	2639	2640	2641	2642	2643	2644	2645	2646	2647	2648	2649	2650	2651	2652	2653	2654	2655	2656	2657	2658	2659	2660	2661	2662	2663	2664	2665	2666	2667	2668	2669	2670	2671	2672	2673	2674	2675	2676	2677	2678	2679	2680	2681	2682	2683	2684	2685	2686	2687	2688	2689	2690	2691	2692	2693	2694	2695	2696	2697	2698	2699	2700	2701	2702	2703	2704	2705	2706	2707	2708	2709	2710	2711	2712	2713	2714	2715	2716	2717	2718	2719	2720	2721	2722	2723	2724	2725	2726	2727	2728	2729	2730	2731	2732	2733	2734	2735	2736	2737	2738	2739	2740	2741	2742	2743	2744	2745	2746	2747	2748	2749	2750	2751	2752	2753	2754	2755	2756	2757	2758	2759	2760	2761	2762	2763	2764	2765	2766	2767	2768	2769	2770	2771	2772	2773	2774	2775	2776	2777	2778	2779	2780	2781	2782	2783	2784	2785	2786	2787	2788	2789	2790	2791	2792	2793	2794	2795	2796	2797	2798	2799	2800	2801	2802	2803	2804	2805	2806	2807	2808	2809	2810	2811	2812	2813	2814	2815	2816	2817	2818	2819	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829	2830	2831	2832	2833	2834	2835	2836	2837	2838	2839	2840	2841	2842	2843	2844	2845	2846	2847	2848	2849	2850	2851	2852	2853	2854	2855	2856	2857	2858	2859	2860	2861	2862	2863	2864	2865	2866	2867	2868	2869	2870	2871	2872	2873	2874	2875	2876	2877	2878	2879	2880	2881	2882	2883	2884	2885	2886	2887	2888	2889	2890	2891	2892	2893	2894	2895	2896	2897	2898	2899	2900	2901	2902	2903	2904	2905	2906	2907	2908	2909	2910	2911	2912	2913	2914	2915	2916	2917	2918	2919	2920	2921	2922	2923	2924	2925	2926	2927	2928	2929	2930	2931	2932	2933	2934	2935	2936	2937	2938	2939	2940	2941	2942	2943	2944	2945	2946	2947	2948	2949	2950	2951	2952	2953	2954	2955	2956	2957	2958	2959	2960	2961	2962	2963	2964	2965	2966	2967	2968	2969	2970	2971	2972	2973	2974	2975	2976	2977	2978	2979	2980	2981	2982	2983	2984	2985	2986	2987	2988	2989	2990	2991	2992	2993	2994	2995	2996	2997	2998	2999	3000	3001	3002	3003	3004	3005	3006	3007	3008	3009	3010	3011	3012	3013	3014	3015	3016	3017	3018	3019	3020	3021	3022	3023	3024	3025	3026	3027	3028	3029	3030	3031	3032	3033	3034	3035	3036	3037	3038	3039	3040	3041	3042	3043	3044	3045	3046	3047	3048	3049	3050	3051	3052	3053	3054	3055	3056	3057	3058	3059	3060	3061	3062	3063	3064	3065	3066	3067	3068	3069	3070	3071	3072	3073	3074	3075	3076	3077	3078	3079	3080	3081	3082	3083	3084	3085	3086	3087	3088	3089	3090	3091	3092	3093	3094	3095	3096	3097	3098	3099	3100	3101	3102	3103	3104	3105	3106	3107	3108	3109	3110	3111	3112	3113	3114	3115	3116	3117	3118	3119	3120	3121	3122	3123	3124	3125	3126	3127	3128	3129	3130	3131	3132	3133	3134	3135	3136	3137	3138	3139	3140	3141	3142	3143	3144	3145	3146	3147	3148	3149	3150	3151	3152	3153	3154	3155	3156	3157	3158	3159	3160	3161	3162	3163	3164	3165	3166	3167	3168	3169	3170	3171	3172	3173	3174	3175	3176	3177	3178	3179	3180	3181	3182	3183	3184	3185	3186	3187	3188	3189	3190	3191	3192	3193	3194	3195	3196	3197	3198	3199	3200	3201	3202	3203	3204	3205	3206	3207	3208	3209	3210	3211	3212	3213	3214	3215	3216	3217	3218	3219	3220	3221	3222	3223	3224	3225	3226	3227	3228	3229	3230	3231	3232	3233	3234	3235	3236	3237	3238	3239	3240	3241	3242	3243	3244	3245	3246	3247	3248	3249	3250	3251	3252	3253	3254	3255	3256	3257	3258	3259	3260	3261	3262	3263	3264	3265	3266	3267	3268	3269	3270	3271	3272	3273	3274	3275	3276	3277	3278	3279	3280	3281	3282	3283	3284	3285	3286	3287	3288	3289	3290	3291	3292	3293	3294	3295	3296	3297	3298	3299	3300	3301	3302	3303	3304	3305	3306	3307	3308	3309	3310	3311	3312	3313	3314	3315	3316	3317	3318	3319	3320	3321	3322	3323	3324	3325	3326	3327	3328	3329	3330	3331	3332	3333	3334	3335	3336	3337	3338	3339	3340	3341	3342	3343	3344	3345	3346	3347	3348	3349	3350	3351	3352	3353	3354	3355	3356	3357	3358	3359	3360	3361	3362	3363	3364	336
------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	-----

PLATE XII

A THREE DIMENSIONAL MODEL OF THE YOUNGSTOWN
PLOTS SHOWING PLOT RELIEF AND POSITION
OF JUNE (1953) ISOPROBES

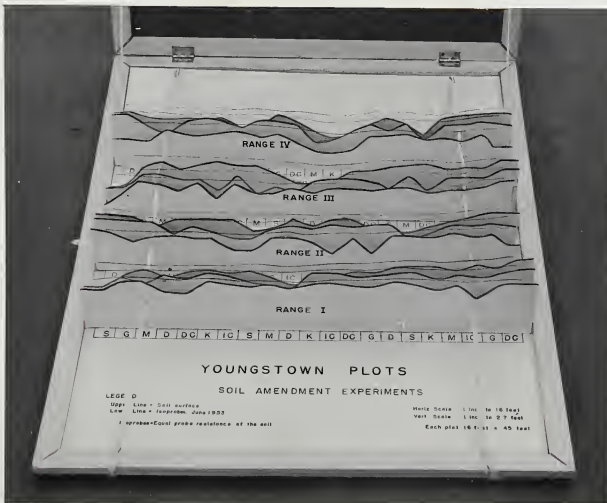
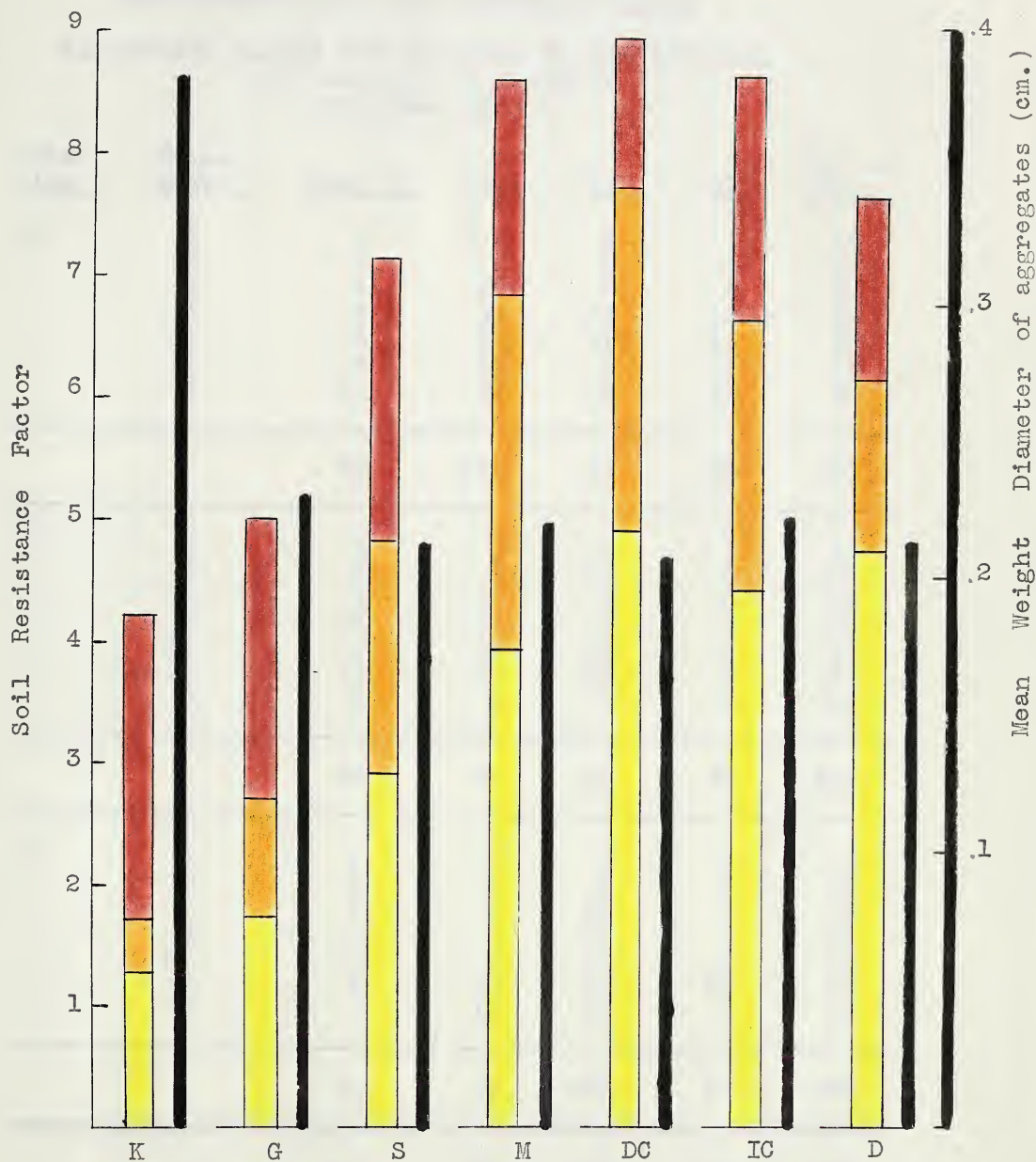


PLATE XIII

YOUNGSTOWN PLOTS

HARDNESS AND AGGREGATE ANALYSIS OF SURFACE SOIL



LEGEND



Resistance factor for 3rd inch of surface soil

Resistance factor for 2nd inch of surface soil

Resistance factor for 1st inch of surface soil

TABLE 8

PENETROMETER DATA FOR YOUNGSTOWN PLOTS

RESISTANCE FACTOR FOR 1ST INCH OF SURFACE SOIL
AND ANALYSIS OF VARIANCE
September 1953

<u>Rotation</u>	<u>Treatments</u>	<u>Rep. I.</u>	<u>II.</u>	<u>III.</u>	<u>IV.</u>	<u>Rot. x Trt.</u>
A	K	3	1	5	7	16
	G	3	6	2	3	14
	S	4	27	4	8	43
	M	7	31	15	10	63
	DC	36	25	11	11	83
	IC	8	16	6	10	40
	D	25	32	16	19	92
		86	138	59	68	351
B	K	3	3	5	3	14
	G	9	9	11	5	34
	S	5	10	5	6	26
	M	24	21	4	5	54
	DC	8	19	15	5	47
	IC	13	13	10	6	42
	D	6	9	3	4	22
		68	84	53	34	239
C	K	2	8	3	2	15
	G	4	1	6	2	13
	S	6	3	25	3	37
	M	5	5	14	1	25
	DC	13	6	21	5	45
	IC	6	19	25	26	76
	D	3	15	32	5	55
		39	57	126	44	266
		193	279	238	146	856

TABLE II

PERCENTAGE OF THE TOTAL POPULATION OF THE UNITED STATES, 1900-1910, WHO ARE NATIVE-BORN AND NATURALIZED CITIZENS, BY SEX AND COLOR.

Year	White	Colored	Male	Female	Total
1900	75.0	75.0	75.0	75.0	75.0
1905	75.0	75.0	75.0	75.0	75.0
1910	75.0	75.0	75.0	75.0	75.0
1915	75.0	75.0	75.0	75.0	75.0
1920	75.0	75.0	75.0	75.0	75.0
1925	75.0	75.0	75.0	75.0	75.0
1930	75.0	75.0	75.0	75.0	75.0
1935	75.0	75.0	75.0	75.0	75.0
1940	75.0	75.0	75.0	75.0	75.0
1945	75.0	75.0	75.0	75.0	75.0
1950	75.0	75.0	75.0	75.0	75.0
1955	75.0	75.0	75.0	75.0	75.0
1960	75.0	75.0	75.0	75.0	75.0
1965	75.0	75.0	75.0	75.0	75.0
1970	75.0	75.0	75.0	75.0	75.0
1975	75.0	75.0	75.0	75.0	75.0
1980	75.0	75.0	75.0	75.0	75.0
1985	75.0	75.0	75.0	75.0	75.0
1990	75.0	75.0	75.0	75.0	75.0
1995	75.0	75.0	75.0	75.0	75.0
2000	75.0	75.0	75.0	75.0	75.0
2005	75.0	75.0	75.0	75.0	75.0
2010	75.0	75.0	75.0	75.0	75.0
2015	75.0	75.0	75.0	75.0	75.0
2020	75.0	75.0	75.0	75.0	75.0
2025	75.0	75.0	75.0	75.0	75.0
2030	75.0	75.0	75.0	75.0	75.0
2035	75.0	75.0	75.0	75.0	75.0
2040	75.0	75.0	75.0	75.0	75.0
2045	75.0	75.0	75.0	75.0	75.0
2050	75.0	75.0	75.0	75.0	75.0
2055	75.0	75.0	75.0	75.0	75.0
2060	75.0	75.0	75.0	75.0	75.0
2065	75.0	75.0	75.0	75.0	75.0
2070	75.0	75.0	75.0	75.0	75.0
2075	75.0	75.0	75.0	75.0	75.0
2080	75.0	75.0	75.0	75.0	75.0
2085	75.0	75.0	75.0	75.0	75.0
2090	75.0	75.0	75.0	75.0	75.0
2095	75.0	75.0	75.0	75.0	75.0
2100	75.0	75.0	75.0	75.0	75.0

TABLE 8 (cont'd.)

ANALYSIS OF VARIANCE FOR RESISTANCE FACTOR FOR 1ST INCH OF
SURFACE SOIL

<u>Treatment</u>		<u>Average</u>	
K	45	K	3.8
G	61	G	5.1
S	106	S	8.8
M	142	M	11.8
DC	175	DC	14.6
IC	158	IC	13.2
D	169	D	14.1
<hr/>			
856			

Source of Variation	SS	DF	MS	F	5%	1%
Reps.	469	3	156.3	.98		
Rotations	244	2	122	.76		
Error (1)	960	6	160			
Trts.	1385	6	230.8	6.52**		
Rot. x Trts.	1107	12	92.3	2.61	1.95	2.96
Error (2)	1910	54	35.4			
TOTAL	6075					

LSD at 5% level of significance = 5.24

LSD at 1% level of significance = 7.07

TABLE 9

PENETROMETER DATA FOR YOUNGSTOWN PLOTS

RESISTANCE FACTOR FOR 2ND INCH OF SURFACE SOIL
AND ANALYSIS OF VARIANCE
September 1953.

<u>Rotation</u>	<u>Treatments</u>	<u>Rep. I.</u>	<u>II.</u>	<u>III.</u>	<u>IV.</u>	<u>Rot. x Trt.</u>
A	K	4	10	8	8	30
	G	4	15	4	12	35
	S	9	27	8	14	58
	M	36	36	21	31	124
	DC	36	27	23	31	117
	IC	15	21	24	21	81
	D	26	34	18	26	104
		130	170	106	143	549
B	K	3	4	5	5	17
	G	8	21	10	7	46
	S	18	10	16	11	55
	M	24	24	9	14	71
	DC	12	25	23	19	79
	IC	10	17	19	16	62
	D	14	17	7	9	47
		89	118	89	81	377
C	K	5	10	7	3	25
	G	3	3	4	9	19
	S	9	9	27	7	52
	M	7	15	23	5	50
	DC	25	10	30	15	80
	IC	6	28	34	28	96
	D	6	15	33	15	69
		61	90	158	82	391
		280	378	353	306	1317

TABLE

TABLE SHOWING THE RESULTS OF THE INVESTIGATION

CONDUCTED BY THE BUREAU OF THE INSPECTION OF THE ARMY

FOR THE YEAR 1900

NAME	AGE	HEIGHT	WEIGHT	COMPLEXION	HAIR	EYES
1. JAMES	21	5' 10"	160	Fair	Black	Blue
2. JOHN	22	5' 8"	150	Fair	Black	Blue
3. WILLIAM	23	5' 9"	155	Fair	Black	Blue
4. ROBERT	24	5' 11"	165	Fair	Black	Blue
5. EDWARD	25	5' 10"	160	Fair	Black	Blue
6. GEORGE	26	5' 9"	155	Fair	Black	Blue
7. FRANK	27	5' 8"	150	Fair	Black	Blue
8. CHARLES	28	5' 7"	145	Fair	Black	Blue
9. HENRY	29	5' 6"	140	Fair	Black	Blue
10. THOMAS	30	5' 5"	135	Fair	Black	Blue
11. JAMES	31	5' 4"	130	Fair	Black	Blue
12. JOHN	32	5' 3"	125	Fair	Black	Blue
13. WILLIAM	33	5' 2"	120	Fair	Black	Blue
14. ROBERT	34	5' 1"	115	Fair	Black	Blue
15. EDWARD	35	5' 0"	110	Fair	Black	Blue
16. GEORGE	36	4' 11"	105	Fair	Black	Blue
17. FRANK	37	4' 10"	100	Fair	Black	Blue
18. CHARLES	38	4' 9"	95	Fair	Black	Blue
19. HENRY	39	4' 8"	90	Fair	Black	Blue
20. THOMAS	40	4' 7"	85	Fair	Black	Blue
21. JAMES	41	4' 6"	80	Fair	Black	Blue
22. JOHN	42	4' 5"	75	Fair	Black	Blue
23. WILLIAM	43	4' 4"	70	Fair	Black	Blue
24. ROBERT	44	4' 3"	65	Fair	Black	Blue
25. EDWARD	45	4' 2"	60	Fair	Black	Blue
26. GEORGE	46	4' 1"	55	Fair	Black	Blue
27. FRANK	47	4' 0"	50	Fair	Black	Blue
28. CHARLES	48	3' 11"	45	Fair	Black	Blue
29. HENRY	49	3' 10"	40	Fair	Black	Blue
30. THOMAS	50	3' 9"	35	Fair	Black	Blue
31. JAMES	51	3' 8"	30	Fair	Black	Blue
32. JOHN	52	3' 7"	25	Fair	Black	Blue
33. WILLIAM	53	3' 6"	20	Fair	Black	Blue
34. ROBERT	54	3' 5"	15	Fair	Black	Blue
35. EDWARD	55	3' 4"	10	Fair	Black	Blue
36. GEORGE	56	3' 3"	5	Fair	Black	Blue
37. FRANK	57	3' 2"	0	Fair	Black	Blue
38. CHARLES	58	3' 1"	0	Fair	Black	Blue
39. HENRY	59	3' 0"	0	Fair	Black	Blue
40. THOMAS	60	2' 11"	0	Fair	Black	Blue
41. JAMES	61	2' 10"	0	Fair	Black	Blue
42. JOHN	62	2' 9"	0	Fair	Black	Blue
43. WILLIAM	63	2' 8"	0	Fair	Black	Blue
44. ROBERT	64	2' 7"	0	Fair	Black	Blue
45. EDWARD	65	2' 6"	0	Fair	Black	Blue
46. GEORGE	66	2' 5"	0	Fair	Black	Blue
47. FRANK	67	2' 4"	0	Fair	Black	Blue
48. CHARLES	68	2' 3"	0	Fair	Black	Blue
49. HENRY	69	2' 2"	0	Fair	Black	Blue
50. THOMAS	70	2' 1"	0	Fair	Black	Blue
51. JAMES	71	2' 0"	0	Fair	Black	Blue
52. JOHN	72	1' 11"	0	Fair	Black	Blue
53. WILLIAM	73	1' 10"	0	Fair	Black	Blue
54. ROBERT	74	1' 9"	0	Fair	Black	Blue
55. EDWARD	75	1' 8"	0	Fair	Black	Blue
56. GEORGE	76	1' 7"	0	Fair	Black	Blue
57. FRANK	77	1' 6"	0	Fair	Black	Blue
58. CHARLES	78	1' 5"	0	Fair	Black	Blue
59. HENRY	79	1' 4"	0	Fair	Black	Blue
60. THOMAS	80	1' 3"	0	Fair	Black	Blue
61. JAMES	81	1' 2"	0	Fair	Black	Blue
62. JOHN	82	1' 1"	0	Fair	Black	Blue
63. WILLIAM	83	1' 0"	0	Fair	Black	Blue
64. ROBERT	84	0' 11"	0	Fair	Black	Blue
65. EDWARD	85	0' 10"	0	Fair	Black	Blue
66. GEORGE	86	0' 9"	0	Fair	Black	Blue
67. FRANK	87	0' 8"	0	Fair	Black	Blue
68. CHARLES	88	0' 7"	0	Fair	Black	Blue
69. HENRY	89	0' 6"	0	Fair	Black	Blue
70. THOMAS	90	0' 5"	0	Fair	Black	Blue
71. JAMES	91	0' 4"	0	Fair	Black	Blue
72. JOHN	92	0' 3"	0	Fair	Black	Blue
73. WILLIAM	93	0' 2"	0	Fair	Black	Blue
74. ROBERT	94	0' 1"	0	Fair	Black	Blue
75. EDWARD	95	0' 0"	0	Fair	Black	Blue
76. GEORGE	96	0' 0"	0	Fair	Black	Blue
77. FRANK	97	0' 0"	0	Fair	Black	Blue
78. CHARLES	98	0' 0"	0	Fair	Black	Blue
79. HENRY	99	0' 0"	0	Fair	Black	Blue
80. THOMAS	100	0' 0"	0	Fair	Black	Blue

TABLE 9 (cont'd.)

ANALYSIS OF VARIANCE FOR RESISTANCE FACTOR FOR 2ND INCH OF
SURFACE SOIL

<u>Treatments</u>		<u>Average</u>	
K	72	K	6
G	100	G	8.3
S	165	S	13.8
M	245	M	20.4
DC	276	DC	23.0
IC	239	IC	19.9
D	220	D	18.3
<hr/>			
1317			

Source of Variation	SS	DF	MS	F
Reps.	281	3	93.6	
Rotations	652	2	326	2.2
Error (1)	893	6	149	
Trts.	3030	6	505	15.8
Rot. x Trts.	986	12	82	2.5
Error (2)	1739	54	32	
T O T A L	7581			

LSD at 5% level of significance = 4.6

LSD at 1% level of significance = 6.2

TABLE 10

PENETROMETER DATA FOR YOUNGSTOWN PLOTS

RESISTANCE FACTOR FOR 3RD INCH OF SURFACE SOIL
AND ANALYSIS OF VARIANCE
September 1953

<u>Rotation</u>	<u>Treatments</u>	<u>Rep. I.</u>	<u>II.</u>	<u>III.</u>	<u>IV.</u>	<u>Rot. x Trt.</u>
A	K	12*	36	19	11	78
	G	16	23	9	24	72
	S	14	32	14	22	82
	M	36	36	27	36	135
	DC	36	36	30	36	138
	IC	33	30	28	30	121
	D	28	36	24	29	117
		175	229	151	188	743
B	K	3	5	8	10	26
	G	14	30	11	11	66
	S	19	24	20	30	93
	M	30	32	13	31	106
	DC	20	31	23	27	101
	IC	12	22	32	20	86
	D	16	22	12	24	74
		114	166	119	153	552
C	K	7	18	19	3	47
	G	12	9	7	14	42
	S	14	21	29	9	73
	M	8	21	31	9	69
	DC	20	17	30	22	89
	IC	4	30	33	36	103
	D	8	15	36	23	82
		73	131	185	116	505
		362	526	455	457	1800

* The figures in the table are per cent relative tension.

TABLE 2

STATIONARY DATA FOR THE PERIOD 1961-1962
 (The values are in the form of a ratio)

Station	1961	1962	1963	1964	1965	1966
A	1.00	1.00	1.00	1.00	1.00	1.00
B	1.00	1.00	1.00	1.00	1.00	1.00
C	1.00	1.00	1.00	1.00	1.00	1.00
D	1.00	1.00	1.00	1.00	1.00	1.00
E	1.00	1.00	1.00	1.00	1.00	1.00
F	1.00	1.00	1.00	1.00	1.00	1.00
G	1.00	1.00	1.00	1.00	1.00	1.00
H	1.00	1.00	1.00	1.00	1.00	1.00
I	1.00	1.00	1.00	1.00	1.00	1.00
J	1.00	1.00	1.00	1.00	1.00	1.00
K	1.00	1.00	1.00	1.00	1.00	1.00
L	1.00	1.00	1.00	1.00	1.00	1.00
M	1.00	1.00	1.00	1.00	1.00	1.00
N	1.00	1.00	1.00	1.00	1.00	1.00
O	1.00	1.00	1.00	1.00	1.00	1.00
P	1.00	1.00	1.00	1.00	1.00	1.00
Q	1.00	1.00	1.00	1.00	1.00	1.00
R	1.00	1.00	1.00	1.00	1.00	1.00
S	1.00	1.00	1.00	1.00	1.00	1.00
T	1.00	1.00	1.00	1.00	1.00	1.00
U	1.00	1.00	1.00	1.00	1.00	1.00
V	1.00	1.00	1.00	1.00	1.00	1.00
W	1.00	1.00	1.00	1.00	1.00	1.00
X	1.00	1.00	1.00	1.00	1.00	1.00
Y	1.00	1.00	1.00	1.00	1.00	1.00
Z	1.00	1.00	1.00	1.00	1.00	1.00

* The figures in the table are not necessarily
 identical.

TABLE 10 (cont'd.)

ANALYSIS OF VARIANCE FOR RESISTANCE FACTOR FOR 3RD INCH

SURFACE SOIL

September-1953

<u>Treatment</u>		<u>Average</u>	
K	151	K	12.6
G	180	G	15.0
S	248	S	20.7
M	310	M	25.8
DC	328	DC	27.3
IC	310	IC	25.8
D	273	D	22.8

1800

Source of Variation	SS	DF	MS	F
Reps.	647	3	215.6	1.3
Rotations	1135	2	567.5	3.39**
Error (1)	1005	6	167.5	
Trts.	2347	6	391.1	9.5**
Rot. x Trts.	671	12	55.9	1.4
Error (2)	2228	54	41.3	
TOTAL	8033	83		

LSD at 5% level of significance = 5.2

LSD at 1% level of significance = 7.0

354

TABLE 11

SOIL AMENDMENT PLOTS
AGGREGATE ANALYSIS 1953
AND ANALYSIS OF VARIANCE
Mean Weight Diameters

<u>Rotation</u>	<u>Treatments</u>	<u>Rep. I.</u>	<u>II.</u>	<u>III.</u>	<u>IV.</u>	<u>Rot. x Trt.</u>
A	S	.27	.13	.23	.12	.75
	K	.35	.40	.42	.27	1.44
	G	.23	.22	.25	.22	.92
	M	.20	.20	.24	.23	.87
	DC	.24	.20	.22	.26	.92
	IC	.22	.15	.25	.16	.78
	D	.13	.24	.23	.13	.73
		1.64	1.54	1.84	1.39	6.41
B	S	.24	.23	.21	.20	.88
	K	.30	.45	.41	.40	1.56
	G	.23	.21	.26	.22	.92
	M	.16	.20	.21	.29	.86
	DC	.23	.18	.24	.27	.92
	IC	.17	.27	.27	.20	.91
	D	.23	.22	.27	.22	.94
		1.56	1.76	1.87	1.80	6.99
C	S	.21	.23	.29	.21	.94
	K	.35	.41	.38	.43	1.57
	G	.24	.19	.24	.28	.95
	M	.24	.24	.23	.19	.90
	DC	.29	.18	.22	.22	.91
	IC	.30	.24	.23	.20	.97
	D	.19	.22	.22	.20	.83
		1.82	1.71	1.81	1.73	7.07
		5.02	5.01	5.52	4.92	20.47

TABLE 11 (cont'd.)

ANALYSIS OF VARIANCE FOR MEAN WEIGHT DIAMETER

<u>Treatments</u>		<u>Average (cm.)</u>	
S	2.57	S	.21
K	4.57	K	.38
G	2.79	G	.23
M	2.63	M	.22
DC	2.75	DC	.23
IC	2.66	IC	.22
D	2.50	D	.21
<hr/>			
20.47			

Source of Variation	SS	DF	MS	F	5%	1%
Reps.	106	3	35.3	1.37		
Rotation	93	2	46.5	1.80		
Error (1)	135	6	25.8			
Trts.	2682	6	447	26.61**	2.29	3.18
Rot. x Trt.	87	12	7.2	.43		
Error (2)	.0907	54	16.8			
<hr/>						
	.4010					

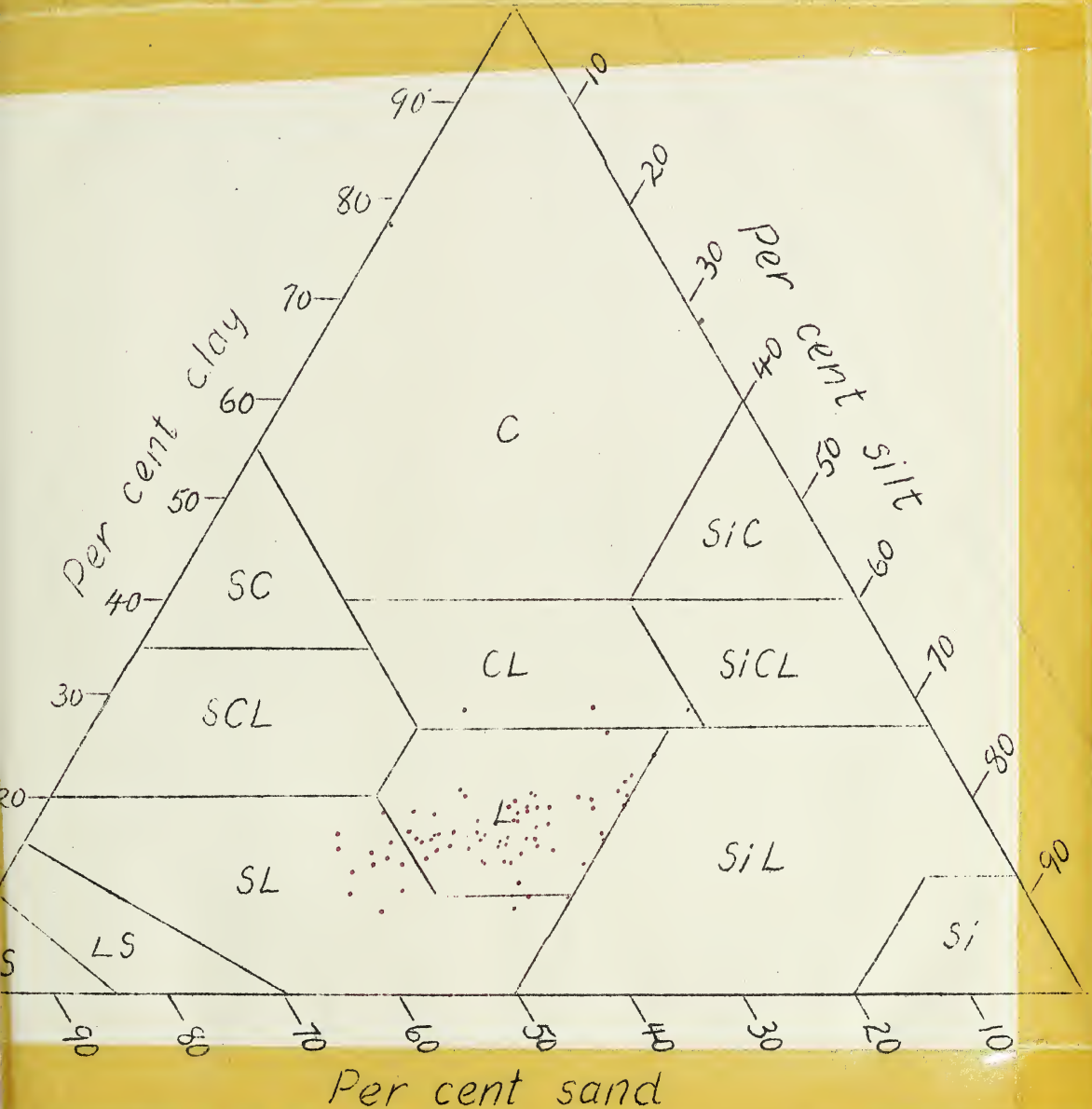
LSD at 5% level of significance = .036

LSD at 1% level of significance = .048

PLATE XIV

YOUNGSTOWN PLOTS

MECHANICAL ANALYSIS OF SURFACE SOIL FROM EACH PLOT



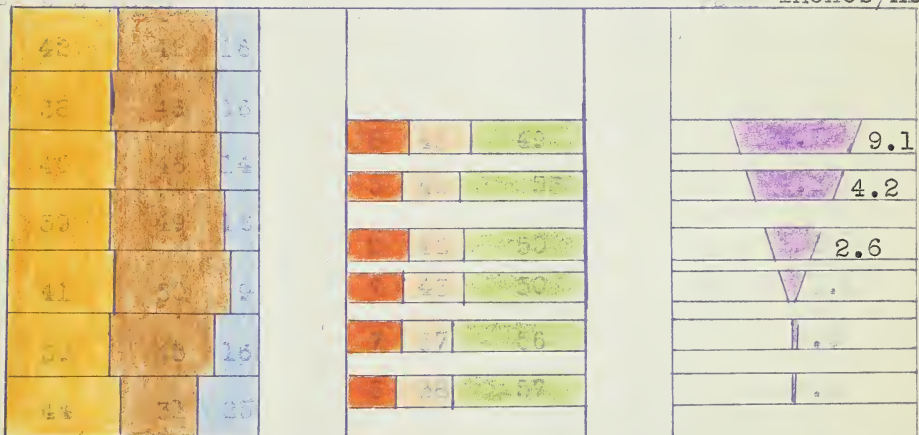
卷之五

Teeth Mechanical Analysis

rate inches/hour



3000

inches/hour

255

LEGEND

Jan 3

311t

Page 2

112


 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100.

1000

TABLE 12

SOLUBLE SALTS IN SEVERAL PROFILE SOIL

SAMPLES FROM YOUNGSTOWN PLOTS

| Range | Plot | Depth | Con- | % | Soluble salts (%) | | | | | |
|-------|------|---------|-------------------------------------|------|-------------------|---|-----------------|------------------------------|------------------|------------------|
| | | | duct-
ivity
mm
hos/
cm. | | N.V.S. | HC ₃ O ₃ ⁻ | Cl ⁻ | SO ₄ ⁼ | Ca ⁺⁺ | Mg ⁺⁺ |
| I | 1 | 0"- 6" | .33 | .11 | | | | | | |
| | | 6"-12" | .41 | .15 | .116 | .006 | .09 | | | .027 |
| | | 12"-18" | .23 | .07 | | | | | | |
| | | 18"-24" | 2.33 | .99 | .027 | | 1.53 | .212 | .025 | .031 |
| | | 24"-30" | 1.91 | .81 | .021 | .006 | 1.03 | .110 | .025 | .058 |
| | | 30"-36" | 2.15 | .92 | .034 | .002 | 1.38 | .095 | .041 | .078 |
| | | 36"-42" | 1.69 | .72 | .054 | .002 | .71 | .067 | .002 | .114 |
| | | 42"-48" | 1.91 | .81 | .051 | .004 | 1.08 | .044 | .012 | .128 |
| | 8 | 0"- 6" | 1.32 | .54 | .114 | .006 | .57 | .060 | .010 | .061 |
| | | 6"-12" | .74 | .29 | | | .38 | | | .077 |
| | | 12"-18" | 2.98 | 1.29 | .048 | - | .74 | .139 | .034 | .169 |
| | | 18"-24" | 3.23 | 1.39 | .026 | .002 | .78 | .144 | .033 | .192 |
| | | 24"-30" | 3.23 | 1.39 | .031 | .002 | .80 | .154 | .032 | .199 |
| | | 30"-36" | 2.86 | .78 | .024 | .002 | .79 | .137 | .024 | .181 |
| | | 36"-42" | 3.77 | 1.62 | .024 | - | .96 | .230 | .036 | .185 |
| | | 42"-48" | 3.60 | 1.56 | .012 | .002 | .82 | .236 | .033 | |
| | 15 | 0"- 6" | .37 | .13 | | | | | | |
| | | 6"-12" | 1.72 | .73 | .046 | - | .35 | tr. | tr. | .171 |
| | | 12"-18" | 4.84 | 2.11 | .044 | - | 1.39 | .178 | .053 | .370 |
| | | 18"-24" | 3.37 | 1.45 | .026 | - | .83 | .111 | .034 | .250 |
| | | 24"-30" | 3.23 | 1.39 | .036 | - | .71 | .041 | .017 | .304 |
| | | 30"-36" | 3.44 | 1.48 | .039 | - | .60 | .046 | .022 | .268 |
| | | 36"-42" | 5.00 | 2.18 | .029 | - | 1.49 | .226 | .042 | .371 |
| | | 42"-48" | 4.94 | 2.16 | .017 | - | 1.43 | .176 | .047 | .378 |
| II | 3 | 0"- 6" | .27 | .09 | | - | | | | |
| | | 6"-12" | .51 | .19 | .041 | .012 | .07 | | | .049 |
| | | 12"-18" | 1.41 | .59 | .068 | .002 | .35 | | | .148 |
| | | 18"-24" | 3.90 | 1.69 | .024 | .002 | 1.25 | .210 | .046 | .186 |
| | | 24"-30" | 2.70 | 1.16 | .034 | .002 | .71 | .093 | .027 | .195 |
| | | 30"-36" | 2.13 | .91 | .034 | - | 1.00 | .062 | .018 | .160 |
| | | 36"-42" | 1.97 | .84 | .034 | .002 | .53 | .106 | .015 | .101 |
| | | 42"-48" | .61 | .23 | .122 | .004 | .09 | | | .138 |
| | 10 | 0"- 6" | .21 | .07 | | | | | | |
| | | 6"-12" | .41 | .15 | | | .04 | | | .051 |
| | | 12"-18" | 1.95 | .83 | .017 | | .45 | .063 | .027 | .122 |
| | | | | | | | | | | |

TABLE 12 (cont'd.)

SOLUBLE SALTS IN SEVERAL PROFILE SOIL

SAMPLES FROM YOUNGSTOWN PLOTS

| Range | Plot | Depth | Con- | %
N.V.S. | Soluble salts (%) | | | | | |
|-------|------|---------|-------------------------------------|-------------|-------------------------------|-----------------|------------------------------|------------------|------------------|-----------------|
| | | | duct-
ivity
mm
hos/
cm. | | HCO ₃ ⁻ | Cl ⁻ | SO ₄ ⁼ | Ca ⁺⁺ | Mg ⁺⁺ | Na ⁺ |
| II | 10 | 18"-24" | 2.57 | 1.10 | .056 | | .40 | .130 | .033 | .126 |
| | | 24"-30" | 2.07 | .87 | .048 | .002 | .51 | .071 | .032 | .115 |
| | | 30"-36" | 2.70 | 1.16 | .034 | .002 | .65 | .172 | .035 | .120 |
| | | 36"-42" | 3.23 | 1.39 | .026 | | .90 | .213 | .039 | .125 |
| | | 42"-48" | 3.37 | 1.45 | .046 | .002 | .82 | .248 | .034 | .119 |
| | 17 | 0"-6" | .17 | .03 | | | | | | |
| | | 6"-12" | .75 | .30 | .002 | | .01 | | | .005 |
| | | 12"-18" | .21 | .08 | | | | | | |
| | | 18"-24" | .15 | .05 | | | | | | |
| | | 24"-30" | .18 | .06 | | | | | | |
| | | 30"-36" | .23 | .09 | | | | | | |
| | | 36"-42" | .20 | .07 | | | | | | |
| | | 42"-48" | .38 | .14 | | | | | | |
| III | 5 | 0"-6" | .27 | .09 | | | | | | |
| | | 6"-12" | .27 | .09 | | | | | | |
| | | 12"-18" | .58 | .22 | .081 | .002 | .05 | | | .076 |
| | | 18"-24" | 1.71 | .73 | .051 | .002 | .35 | .046 | .013 | .177 |
| | | 24"-30" | 1.84 | .78 | .048 | .002 | .40 | .035 | .014 | .144 |
| | | 30"-36" | 2.49 | 1.07 | .036 | .004 | .58 | .085 | .023 | .144 |
| | | 36"-42" | 3.37 | 1.45 | .021 | | .96 | .220 | .030 | .146 |
| | | 42"-48" | .74 | .30 | .102 | .002 | .12 | | | .072 |
| | 12 | 0"-6" | .40 | .14 | .026 | .004 | .01 | | | .041 |
| | | 6"-12" | 4.04 | 1.74 | .026 | | 1.25 | .097 | .047 | .305 |
| | | 12"-18" | 4.62 | 2.03 | .034 | .002 | 1.45 | .180 | .055 | |
| | | 18"-24" | 3.94 | 1.70 | .039 | .004 | 1.18 | .153 | .044 | .240 |
| | | 24"-30" | 3.23 | 1.39 | .044 | .002 | .75 | .056 | .032 | .280 |
| | | 30"-36" | 4.15 | 1.78 | .034 | .002 | 1.09 | .170 | .044 | .285 |
| | | 36"-42" | 3.76 | 1.62 | .044 | | .94 | .123 | .036 | .255 |
| | | 42"-48" | 3.37 | 1.45 | .041 | | .88 | .075 | .029 | .260 |
| | 19 | 0"-6" | 2.94 | 1.28 | .017 | .002 | .74 | .154 | .033 | .135 |
| | | 6"-12" | | | | | | | | |
| | | 12"-18" | 3.68 | 1.58 | .054 | .002 | .08 | .056 | .026 | .261 |
| | | 18"-24" | 2.49 | 1.07 | .056 | .002 | .67 | .020 | .014 | .244 |
| | | 24"-30" | 3.59 | 1.56 | .039 | .004 | .90 | .125 | .030 | .265 |
| | | 30"-36" | 4.15 | 1.79 | .026 | .004 | .84 | .183 | .028 | .310 |

TABLE 12 (cont'd.)

SOLUBLE SALTS IN SEVERAL PROFILE SOIL

SAMPLES FROM YOUNGSTOWN PLOTS

| Ra-
nge | Plot | Depth | Con-
duct-
ivity
mm
hos/
cm. | %
N.V.S. | Soluble salts (%) | | | | | |
|------------|------|---------|---|-------------|-------------------------------|-----------------|------------------------------|------------------|------------------|-----------------|
| | | | | | HCO ₃ ⁻ | Cl ⁻ | SO ₄ ⁼ | Ca ⁺⁺ | Mg ⁺⁺ | Na ⁺ |
| III | 19 | 36"-42" | 2.31 | .99 | .044 | .004 | .48 | .045 | .014 | .160 |
| | | 42"-48" | 2.23 | 1.01 | .044 | .002 | .49 | .049 | .017 | .165 |
| IV | 7 | 0"-6" | .19 | .03 | | | | | | |
| | | 6"-12" | .29 | .09 | | | | | | |
| | | 12"-18" | .19 | .03 | | | | | | |
| | | 18"-24" | - | | | | | | | |
| | | 24"-30" | - | | | | | | | |
| | | 30"-36" | .34 | .11 | | | | | | |
| | | 36"-42" | .50 | .19 | .075 | .008 | .08 | | | .049 |
| | | 42"-48" | .61 | .23 | .048 | .012 | .08 | | | .064 |
| | 14 | 0"-6" | .46 | .15 | .012 | .010 | .02 | | | .017 |
| | | 6"-12" | .40 | .14 | .088 | .002 | .02 | | | .039 |
| | | 12"-18" | .45 | .15 | .066 | | .05 | | | .047 |
| | | 18"-24" | .81 | .31 | .066 | .006 | .93 | | | .074 |
| | | 24"-30" | .72 | .28 | .063 | .006 | .09 | | | .076 |
| | | 30"-36" | 3.30 | 1.42 | .041 | .036 | .85 | .178 | .051 | .159 |
| | | 36"-42" | 3.76 | 1.62 | .034 | .004 | 1.01 | .248 | .051 | .151 |
| | | 42"-48" | 3.94 | 1.70 | .054 | .012 | 1.13 | .244 | .053 | .180 |
| | 21 | 0"-6" | .33 | .11 | | | | | | |
| | | 6"-12" | .32 | .11 | | | | | | |
| | | 12"-18" | .28 | .09 | | | | | | |
| | | 18"-24" | .98 | .40 | .078 | .008 | .15 | | | .086 |
| | | 24"-30" | 1.24 | .51 | .080 | .006 | .28 | | | .118 |
| | | 30"-36" | 1.38 | .56 | .063 | .004 | .26 | .005 | .008 | .120 |
| | | 36"-42" | 1.47 | .61 | .071 | .002 | .44 | .005 | .007 | .135 |
| | | 42"-48" | 2.10 | .90 | .051 | .002 | .96 | .029 | .026 | .164 |

NOTE:

% N.U.S. were determined by interpolating conductivity readings from a graph on which conductivity and per cent non volatile salts of many samples were plotted in the Soils lab.

Where the conductivity was below .4 mm.hos./cm.

no soluble salt determinations were made.

TABLE 13

TOTAL NITROGEN DETERMINATION OF SOME YOUNGSTOWN
PLOT SOILS

| Sample | % N
(oven-dry basis) | % O.M. (N x 20) |
|--------------------|-------------------------|-----------------|
| Range I - Plot 5 | .108 | 2.16 |
| Range II - Plot 20 | .181 | 3.62 |
| Range III - Plot 8 | .203 | 4.06 |
| Range IV - Plot 8 | .177 | 3.54 |
| Range IV - Plot 19 | .107 | 2.14 |

DISCUSSION

The field and laboratory studies all indicate one distinct feature - great variability in the physical properties and chemical composition of surface and sub-surface soils within a small area.

There is no doubt that native vegetation reflects soil characteristics and the Youngstown plots are a good example. Thus it may be noted that the buckbrush patches had good permeable profiles and consequent grain yields were good. On the contrary the sparse growth on the eroded pits indicated adverse factors were at work, and here were found poor surface tilth and very low permeability. Grass and sage areas gave average grain yields.

The barley and wheat data indicate that some of the soil amendments used tended to increase yields, and penetrometer and soil aggregate analyses show that a few had a beneficial effect on soil structure. The soil variation however, tended to mask the effects of treatments on crop yield. The second crop year was much more favourable than the first, and effects of soil amendments began to show. Eventually it is possible that plot borders will be visually recognizable by the treatment effects. Generally, krillium, sulphur and gypsum treatments increased yields and improved

soil structure. The magnitude of the increase however fell far short of justifying the expenditure required in applying the amendments. Only under a much more intensive cropping system would such an outlay for soil amendments be practical.

The resistance factor for the first three inches of surface soil was significantly lowest for the gypsum, krilium and sulphur treatments while only the krilium treatments gave a significantly higher mean weight diameter for stable soil aggregates. The September isoprobes showed a greater average depth for these three treatments compared with the remaining treatments. Assessment of these facts is difficult with only one year's data. The importance of the various cultural practices and the effects of the soil amendments will probably not appear for several years.

Some treatments gave unexpected results. There seemed to be a depressed yield with increased rates of krilium. In 1952 the krilium @ 1000 lbs./acre gave a higher barley yield than the krilium @ 2000 lbs./acre treatment, though this difference was not significant. However, in 1953 the gypsum treatment, applied and sampled on the remaining portion of the krilium @ 1000 lbs./acre plot gave a significant yield increase over the krilium @ 2000 lbs./acre. One would have been tempted to rate the krilium treatment as the best since this treatment improved the physical condition of the soil. Another unexpected result was the effect of deep cultivation,

which one might have expected to reduce the resistance to the probe on the penetrometer. Deep cultivation treatment on the contrary gave a high resistance factor for the surface soil. This however might have been predicted since, due to circumstances, the deep cultivation treatment was done in the spring when the moisture content was high. Soil puddling resulted. This effect was also demonstrated by the low September isoprobe average..

The effects of irrigation and treatments on the physical structure of solodized solonetz soils is noticeable in the June and September isoprobe averages (Table 5). Attention is drawn to the varying depth of individual isoprobes illustrated in Plate XVI and XIX. The June isoprobe averages indicate that the depth of isoprobes varied in a uniform manner, as no significant difference was evident between treatments. The krilium, sulphur, and gypsum treatments have a significantly lower isoprobe average than the other treatments in September. This is important since it portrays their beneficial effect on soil structure. Looking at the plot profile diagram again, attention is drawn to plots where the September isoprobes were much lower than the June isoprobes. Theoretically, this increasing depth of isoprobes is the expected future results. There was a decrease in the average depth of September isoprobes compared with the June averages. The soil seemed to harden in layers

as the same resistance was encountered at different and varying depths in some plots. In the fall, the surface soil in some plots was so hard that it was impossible to push the penetrometer probe through the crust. No doubt the greater depth of June isoprobes was due to a higher soil moisture content and possibly winter effects on the soil structure. It will be interesting to compare future penetrometer readings with the 1950 isoprobes.

The mechanical analyses indicate a higher amount of sand in the surface and subsurface soils than one would expect in a soil with such a low percolation rate. The eroded pit profile shows an increase in clay content with decreasing permeability rates, and also shows a high sodium content in the profile. The permeable profile, on the other hand, shows practically no change in the sand and the clay content while the content of soluble salts is negligible.

There is also a high amount of calcium and sulphates in the eroded pit profile. The predominant salts in the profile in water wells of the area are sodium and calcium sulphates. The presence of calcium sulphate in the subsoil is an aid to soil reclamation particularly where this gypsum is close enough to the surface to be brought up and mixed with the surface soil by deep ploughing. This is currently

being tried out in other plots at the test site. Deep rooted plants may also bring back to the surface substantial amounts of calcium.

The high conductivity of certain profiles and the high percentage of non-volatile salts shows clearly the salinity problem. The addition of chemical amendments to lower the exchangeable sodium salts, and provision for drainage, are measures that are necessary to make such soil productive.

The color and depth of the surface soil is generally indicative of fertility. Based on these features, and the nitrogen determinations, the Hemaruka soil would not be classified as a highly fertile soil. It is, no doubt, like other Alberta soils low in phosphorus. The value, however, of commercial fertilizers must for some time be a secondary problem in these soils where heterogeneity and poor physical characteristics dominate the crop picture.

Sweet clover growth was not advanced enough in 1953 to show any effects in soil structure or soil fertility, but no doubt in time, beneficial effects will be noticed. A fertility program including the use of legume crops is certainly advocated.

Great variations in the chemical composition and physical properties of the soil was noticed. It is suggested that this heterogeneity can be changed only by a mixing of

surface and subsoil. This mixing would be achieved in part by the large scale levelling under an irrigation program. This levelling would result in soil homogeneity and better physical and chemical properties.

While some soil amendments have improved the physical and chemical properties of the soil, the cost of application is important. Krilium is not economically practical on a field basis; sulphur and gypsum are much cheaper to apply. It seems that an improvement program based on sound cultural practices inter-related with the application of chemical amendments and good crop rotations would be the most practical and permanent method of reclaiming solodized solonetz soils under irrigation. There is no doubt in the writer's mind that Hemaruka soils are irrigable, but at the same time it is recognized that they are poor soils requiring a great deal of very specialized attention before qualifying as good irrigable land.

CONCLUSIONS

The Youngstown plots show great variations in the physical and chemical properties of the Hemaruka soils. This soil variation masked the effects of plot treatments during the first year. During the second year some of the treatments proved of some value. However the plots are still too young to draw sound conclusions.

Field and laboratory studies did reveal certain physical properties and treatment effects. The average depth of September isoprobes was less than the average June depth. The kriliuim, sulphur and gypsum treatments improved soil structure, as denoted by a lower resistance to penetrometer probe penetration and a significantly deeper isoprobe value in September over the remaining treatments. The manure and deep cultivation treatments did not improve the soil structure. All treatments gave significantly higher yields over the dry check in 1953 while no difference was noted in 1952.

Compared with the irrigated check however, only sulphur, manure and gypsum treatments gave significant increases in 1953.

Permeability studies showed that a large amount of sodium in the profile was responsible for very low permeability

rates. Solodized solonetz soils illustrate the close connection between the physical properties of a soil and the chemical composition of the adsorbing complex.

The presence of calcium sulphate in the subsoil will no doubt be of value in reclaiming solodized solonetz soils in this area. The variation of soils in texture, fertility and in physical behaviour in a small area is of practical importance. The writer feels that solodized solonetz soils would be greatly improved if the soil could be mixed thoroughly as by deep ploughing or by levelling operations for irrigation.

There is no doubt in the writer's mind that Hemaruka soils are irrigable providing drainage is assured. It is also recognized that they are poor soils and would require a great deal of very specialized attention before qualifying as good irrigable land.

BIBLIOGRAPHY

- (1) Allan, J.A. Geology of Alberta soils. Research Council of Alberta. Report No. 34. 1943.
- (2) Allan, J.A. The relation of the geology to the soils in the Sounding Creek sheet. Appendix II. Bul. 16. Univ. of Alberta. 1927.
- (3) Baver, L.D. Soil physics. John Wiley & Sons, Inc. New York. Second Edition. 1948.
- (4) Bentley, C.F. A study of some solonetz soil complexes in Saskatchewan. Ph.D. thesis. Univ. of Minn. 1945.
- (5) Bower, C.A., et al. The improvement of an alkali soil by treatment with manure and chemical amendments. Ore. Agr. Exp. Tech. Bul. 22: 1-37. 1951.
- (6) Byers, H.G., C.E. Kellogg, M.S. Anderson, and J. Thorp. Formation of Soil In Soils and Men. U.S.D.A. Yearbook of Agr. 948-978. 1938.
- (7) Call, L.E., and R.I. Throckmorton. The use of dynamite in the improvement of heavy clay soils. Kan. Agr. Exp. Sta. Bul. 209. 1915.
- (8) Chang, W.E. Chemical properties of alkali soils in Mesilla valley, New Mexico. Soil Sci. 75: 233-242. 1953.
- (9) Chepil, W.S. The effect of krillium on soil structure and soil erodibility by wind. In abstracts of Am. Soc. Agr. annual meeting. 1953.
- (10) Culpin, C. Studies on the relation between cultivation implements, soil structure and the crop. Jour. Agr. Sci. 26: 22-35. 1936.
- (11) de Sigmond, A.A. The principles of soil science. Thomas Murphy and Co. London. 1938 (Quoted by Bentley (4)).
- (12) Edminster, T.W., W.L. Turner Jr., J.H. Lillard, and F. Steele. Tests of small core samplers for permeability determinations. Soil Sci. Soc. Am. Proc. 15: 417-420. 1950.

- (1)
- (2)
- (3)
- (4)
- (5)
- (6)
- (7)
- (8)
- (9)
- (10)
- (11)
- (12)
- (13)

- (13) Elson, J. A comparison of the effect of certain cropping and fertilizer practices on soil aggregation. Soil Sci. 50: 339-353. 1940.
- (14) Fitts, J.W., E.S. Lyons, and H.F. Rhoades. Chemical treatment of slick spots. Soil Sci. Soc. Am. Proc. 8: 432-436. 1943.
- (15) Fletcher, P.W., and R.B. Livingstone. Structural improvements following legume growth on unfertilized soil. Soil Sci. Soc. Am. Proc. 14: 347-350. 1949.
- (16) Gardner, R. Some effects of freezing and thawing on the aggregation and permeability of dispersed soils. Soil Sci. 60: 437-443. 1945.
- (17) Gish, R.E., and G.M. Browning. Factors affecting the stability of soil aggregates. Soil Sci. Soc. Am. Proc. 13: 51-55. 1948.
- (18) Glinka, K.D. The great soil groups of the world. (Trans. by C.F. Marbut). Edwards Bros., Ann Arbor. Michigan.
- (19) Goode, W.E., and J.E. Christian. Obtaining soil cores for permeability tests. Ag. Eng. 26: 153-155. 1945.
- (20) Grim, R.E. Clay mineralogy. McGraw-Hill Company Inc. Toronto. 1953.
- (21) Haise, H.R., L.R. Jensen and J. Alessi. The effect of krillium and manure on soil structure and production of sugar beet. In Abstracts of Am. Soc. Agr. annual meeting. 1953.
- (22) Hauser, G.F. Afghan alkali soil and its improvement. Soil Sci. 76: 367-375. 1953.
- (23) Hubbell, D.S., and T.M. Stubblefield. The effects of soil amendments on soil aggregation and on water movement. Soil Sci. Soc. Amer. Proc. 13: 519-522. 1948.
- (24) Jamison, V.C., and H.A. Weaver. Soil hardness measurements in relation to soil moisture content and porosity. Soil Sci. Soc. Amer. Proc. 16: 13-15. 1952.
- (25) Kellogg, C.E. Morphology and genesis of the solonetz soils of western North Dakota. Soil Sci. 38: 483-500. 1934.

- (26) Kelley, W.P. The reclamation of alkali soils. Univ. Calif. Bull. 617. 1937.
- (27) Kelly, O.J. et al. A soil sampling machine for obtaining 2, 3 and 4 inch diameter cores of undisturbed soil to a depth of 6 feet. Soil Sci. 12: 85-87. 1947.
- (28) Krumbein, W.C., and F.J. Pettijohn. Manual of sedimentary petrography. Appleton-Century-Crafts, Inc. New York. 1938.
- (29) Laws, W.D. Tillage tests on Texas blacklands. Soil Sci. 75: 131-136. 1953.
- (30) Laws, W.D. The influence of soil properties on the effectiveness of synthetic soil conditioners. In abstracts of Am. Soc. Agr. annual meeting. 1953.
- (31) Lutz, J.F. Apparatus for collecting undisturbed soil samples. Soil Sci. 64: 399-401. 1947.
- (32) Lyon and Buckman. The nature and properties of soils. The MacMillan Company. New York. 1947.
- (33) MacGregor, J.M. Studies on morphological solonetz soils of Alberta. M.Sc. thesis. Univ. of Alberta. 1938.
- (34) MacGregor, J.M., and F.A. Wyatt. Studies on solonetz soils of Alberta. Soil Sci. 59: 419-435. 1945.
- (35) Martinez, M.B., and M.A. Lugo-Lopez. Influence of subsoil shattering and fertilization on sugar cane production and soil infiltration capacity. Soil Sci. 75: 307-315. 1953.
- (36) Nyhawan, S.D., and L.B. Olmstead. The effect of sample pre-treatment upon soil aggregation in wet sieving analysis. Soil Sci. Soc. Am. Proc. 12: 50-53. 1947.

1981. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1981. 1981. 1981.
1982. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1982. 1982. 1982.
1983. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1983. 1983. 1983.
1984. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1984. 1984. 1984.
1985. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1985. 1985. 1985.
1986. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1986. 1986. 1986.
1987. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1987. 1987. 1987.
1988. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1988. 1988. 1988.
1989. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1989. 1989. 1989.
1990. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1990. 1990. 1990.
1991. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1991. 1991. 1991.
1992. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1992. 1992. 1992.
1993. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1993. 1993. 1993.
1994. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1994. 1994. 1994.
1995. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1995. 1995. 1995.
1996. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1996. 1996. 1996.
1997. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1997. 1997. 1997.
1998. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1998. 1998. 1998.
1999. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 1999. 1999. 1999.
2000. Berlin, G.D.R. The Academy of Sciences of the G.D.R. 2000. 2000. 2000.

- (37) Odynsky, Wm. Solonetz soils in Alberta. Sci. Agr.
25: 780-790. 1945.
- (38) Pettijohn, F.J. Sedimentary rocks. Harper & Brothers.
New York. 1949.
- (39) Reed, I.F. A method of studying soil packing by tractors.
Ag. Eng. 21: 281-282. 1940.
- (40) Richards, L.A. The diagnosis and improvement of saline
and alkali soils. U.S. Reg. Sal. Lab.
Riverside, Calif. 1947.
- (41) Richards, S.S. Soil penetrometer. Soil Sci. Soc. Amer.
Proc. 6: 104-107. 1941.
- (42) Riecken, F.F., and A.E. Stalwick. Physical characteristics
of some solonetz and non solonetz soils of
Saskatchewan. Soil Sci. Soc. Am. Proc.
10: 47-50. 1945.
- (43) Robinson, D.O. and J.B. Page. Soil aggregate stability.
Soil Sci. Soc. Amer. Proc. 15: 25-29.
1950.
- (44) Russell, Sir E.G. Soil conditions and plant growth.
Eighth edition. Longman, Green & Co.,
London. 1950.
- (45) Russell, M.B. Methods of measuring soil structure and
aeration. Soil Sci. 68: 25-39. 1949.
- (46) Schaller, F.W., and K.R. Stockinger. A comparison of 5
methods of expressing aggregate data.
Soil Sci. Soc. Am. Proc. 17: 310-313.
1953.
- (47) Scofield, C.S. Soil, water supply, and soil solution
in irrigation agriculture. In Soils and
Men. U.S.D.A. Yearbook of Agr: 704-716.
1938.
- (48) Shaw, B.T., R.H. Haise, and R.B. Farnsworth. Four
years experience with a soil penetrometer.
Soil Sci. Soc. Amer. Proc. 7: 48-55. 1942.

1. *...* (195)
2. *...* (196)
3. *...* (197)
4. *...* (198)
5. *...* (199)
6. *...* (200)
7. *...* (201)
8. *...* (202)
9. *...* (203)
10. *...* (204)
11. *...* (205)
12. *...* (206)
13. *...* (207)
14. *...* (208)
15. *...* (209)
16. *...* (210)
17. *...* (211)
18. *...* (212)
19. *...* (213)
20. *...* (214)
21. *...* (215)
22. *...* (216)
23. *...* (217)
24. *...* (218)
25. *...* (219)
26. *...* (220)
27. *...* (221)
28. *...* (222)
29. *...* (223)
30. *...* (224)
31. *...* (225)
32. *...* (226)
33. *...* (227)
34. *...* (228)
35. *...* (229)
36. *...* (230)
37. *...* (231)
38. *...* (232)
39. *...* (233)
40. *...* (234)
41. *...* (235)
42. *...* (236)
43. *...* (237)
44. *...* (238)
45. *...* (239)
46. *...* (240)
47. *...* (241)
48. *...* (242)
49. *...* (243)
50. *...* (244)
51. *...* (245)
52. *...* (246)
53. *...* (247)
54. *...* (248)
55. *...* (249)
56. *...* (250)
57. *...* (251)
58. *...* (252)
59. *...* (253)
60. *...* (254)
61. *...* (255)
62. *...* (256)
63. *...* (257)
64. *...* (258)
65. *...* (259)
66. *...* (260)
67. *...* (261)
68. *...* (262)
69. *...* (263)
70. *...* (264)
71. *...* (265)
72. *...* (266)
73. *...* (267)
74. *...* (268)
75. *...* (269)
76. *...* (270)
77. *...* (271)
78. *...* (272)
79. *...* (273)
80. *...* (274)
81. *...* (275)
82. *...* (276)
83. *...* (277)
84. *...* (278)
85. *...* (279)
86. *...* (280)
87. *...* (281)
88. *...* (282)
89. *...* (283)
90. *...* (284)
91. *...* (285)
92. *...* (286)
93. *...* (287)
94. *...* (288)
95. *...* (289)
96. *...* (290)
97. *...* (291)
98. *...* (292)
99. *...* (293)
100. *...* (294)

- (49) Shawarbi, M.Y. Soil chemistry. Chapman & Hall.
London. 1952.
- (50) Sherwoode, L.V., and J.C. Engibous. Status report
on soil conditioning chemicals II.
Soil Sci. Soc. Amer. Proc. 17: 9-16.
1953.
- (51) Slater, C.S. Effect of sample drying on the deter-
minations of the water stability of
soils. Soil Sci. Soc. Am. Proc.
17: 75-76. 1953.
- (52) Smith, D.D. Subsoil conditioning on clay pans for
water conservation. Ag. Eng. 32: 427-
429. 1951.
- (53) Soil Survey Manual. U.S.D.A. 1951.
- (54) Stone, A.A., and I.L. Williams. Measurement of soil
hardness. Ag. Eng. 20: 25-26. 1939.
- (55) Swanson, K. A portable soil core sampler and pene-
trometer. Agr. Jour. 34. 447-451.
1942.
- (56) Toogood, J.A., and T.W. Peters. Comparison of
methods of mechanical analysis of soils.
Can. Jour. Agr. Sci. 33: 159-171.
1953.
- (57) Uhland, R.E. Physical properties of soils as modified
by crops and management. Soil Sci.
Soc. Am. Proc. 4: 361-366. 1949.
- (58) Uhland, R.E., and A.M. O'Neal. Soil permeability
determination for use in soil and water
conservation. U.S.D.A. Soil Cons. Serv.
T.P. 101. 1951.
- (59) Van Bavel, C.H.M. Mean weight - diameter of soil
aggregates as a statistical index of
aggregation. Soil Sci. Soc. Amer.
Proc. 14: 20-23. 1949.
- (60) Van Bavel, C.H.M. Report of the committee on physical
analysis 1951-53. Soil Sci. Soc. Am.
Proc. 17: 416-418. 1953.
- (61) Weiser, H.B. Colloid chemistry. John Wiley & Sons,
Inc., New York. Second edition. 1950.

- (49) Shumakov, A.I., Soil Chemistry, Moscow, 1954.
- (50) Shumakov, A.I., and A.I. Shumakov, Soil Chemistry, Moscow, 1954.
- (51) Shumakov, A.I., and A.I. Shumakov, Soil Chemistry, Moscow, 1954.
- (52) Shumakov, A.I., and A.I. Shumakov, Soil Chemistry, Moscow, 1954.
- (53) Shumakov, A.I., and A.I. Shumakov, Soil Chemistry, Moscow, 1954.
- (54) Shumakov, A.I., and A.I. Shumakov, Soil Chemistry, Moscow, 1954.
- (55) Shumakov, A.I., and A.I. Shumakov, Soil Chemistry, Moscow, 1954.
- (56) Shumakov, A.I., and A.I. Shumakov, Soil Chemistry, Moscow, 1954.
- (57) Shumakov, A.I., and A.I. Shumakov, Soil Chemistry, Moscow, 1954.
- (58) Shumakov, A.I., and A.I. Shumakov, Soil Chemistry, Moscow, 1954.
- (59) Shumakov, A.I., and A.I. Shumakov, Soil Chemistry, Moscow, 1954.
- (60) Shumakov, A.I., and A.I. Shumakov, Soil Chemistry, Moscow, 1954.
- (61) Shumakov, A.I., and A.I. Shumakov, Soil Chemistry, Moscow, 1954.

- (62) Westin, F.C. Solonetz soils of eastern South Dakota. Their properties and genesis. Soil Sci. Soc. Am. Proc. 17: 287-293. 1953.
- (63) Woodruff, C.M. Variation in the state and stability of aggregation as a result of different methods of cropping. Soil Sci. Soc. Amer. Proc. 4: 13-18. 1939.
- (64) Wyatt, F.A. and J.D. Newton. Soil survey of Sounding creek sheet. Bull. 16. Univ. of Alberta. 1927.
- (65) Yoder, R.E. A direct method of aggregate analysis of soils and a study of the physical nature of erosion losses. Jour. Amer. Soc. Agron. 28: 337-351. 1936.
- (66) Zuur, A.J. Drainage and reclamation of lakes and of the Zuiderzee. Soil Sci. 74: 75-89. 1952.

California will be a very good
country for growing
cotton. The soil is very good
and the climate is very good.

(52) 1900, 1901

California is a very good
country for growing
cotton. The soil is very good
and the climate is very good.

(53) 1900, 1901

California is a very good
country for growing
cotton. The soil is very good
and the climate is very good.

(54) 1900, 1901

California is a very good
country for growing
cotton. The soil is very good
and the climate is very good.

(55) 1900, 1901

California is a very good
country for growing
cotton. The soil is very good
and the climate is very good.

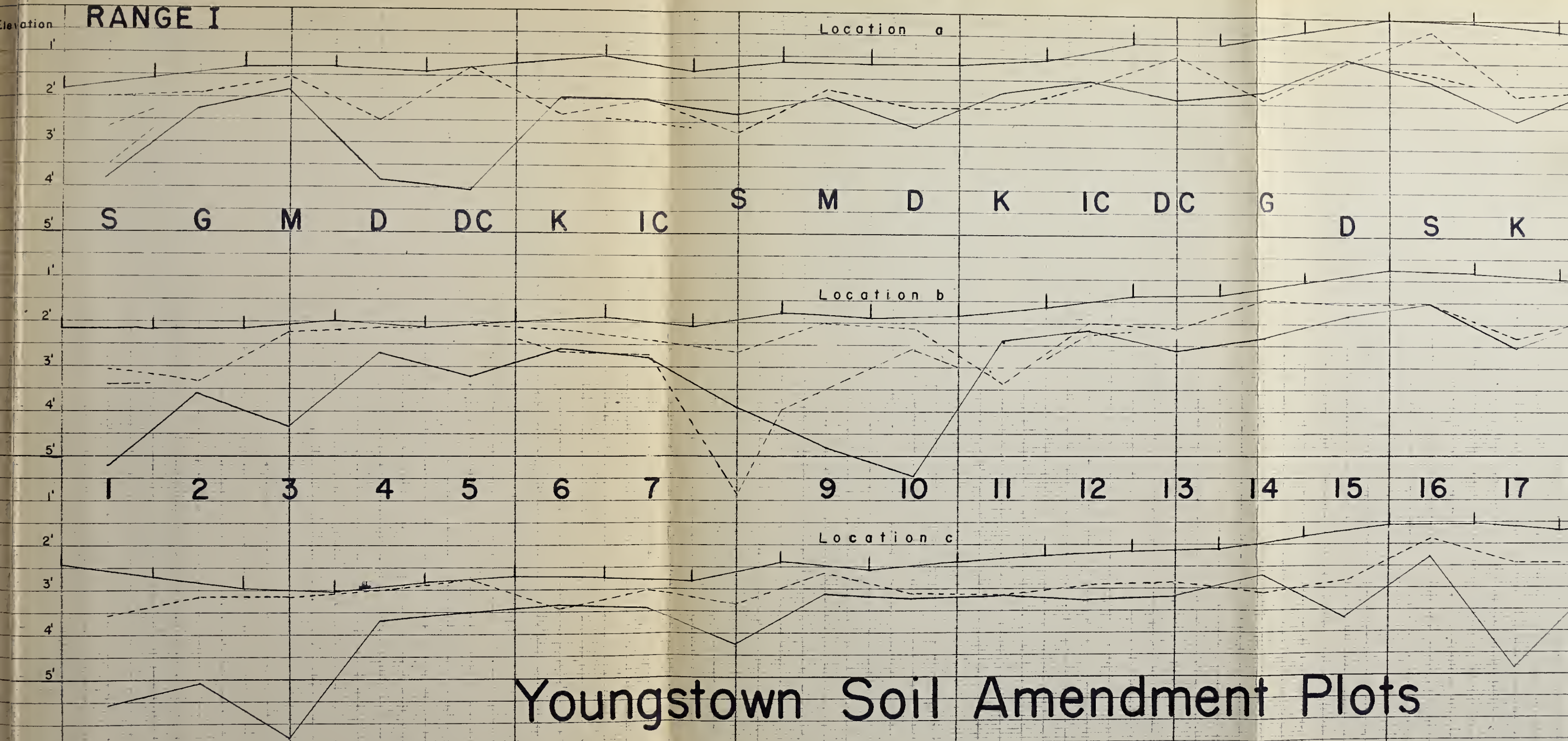
(56) 1900, 1901

APPENDIX

TABLE 14

General
Geological Formations in Alberta

| System | Formations | Origin | Materials and Remarks |
|---------------------|---------------------------------|-------------|--|
| Tertiary | Paskapoo | Continental | sandstone, shale
conglomerate sili-
ceous limestone |
| Upper
Cretaceous | Edmonton | Continental | gray, bentonitic sand-
stones and shale: |
| | St. Mary River | | grey, greenish and
carbonaceous shale. |
| | Bearpaw | Marine | grey, brown, and green
shale, in part bent-
onitic. Bentonite:
limy concretions
grey glauconitic
sandstone. |
| | Belly River Series
Pale beds | Continental | Bentonite sandstone,
grey, yellow and
dark shale. |
| | Foremost | Continental | Light, grey, sand-
stone, shale |
| | Pakowki | Marine | Dark shale, some
sandy bed. |
| | Milk River | Continental | sandstone and sandy
shale. |
| | Alberta shale | Marine | Dark shale, sandy
shale: sandstone
and pebble. |

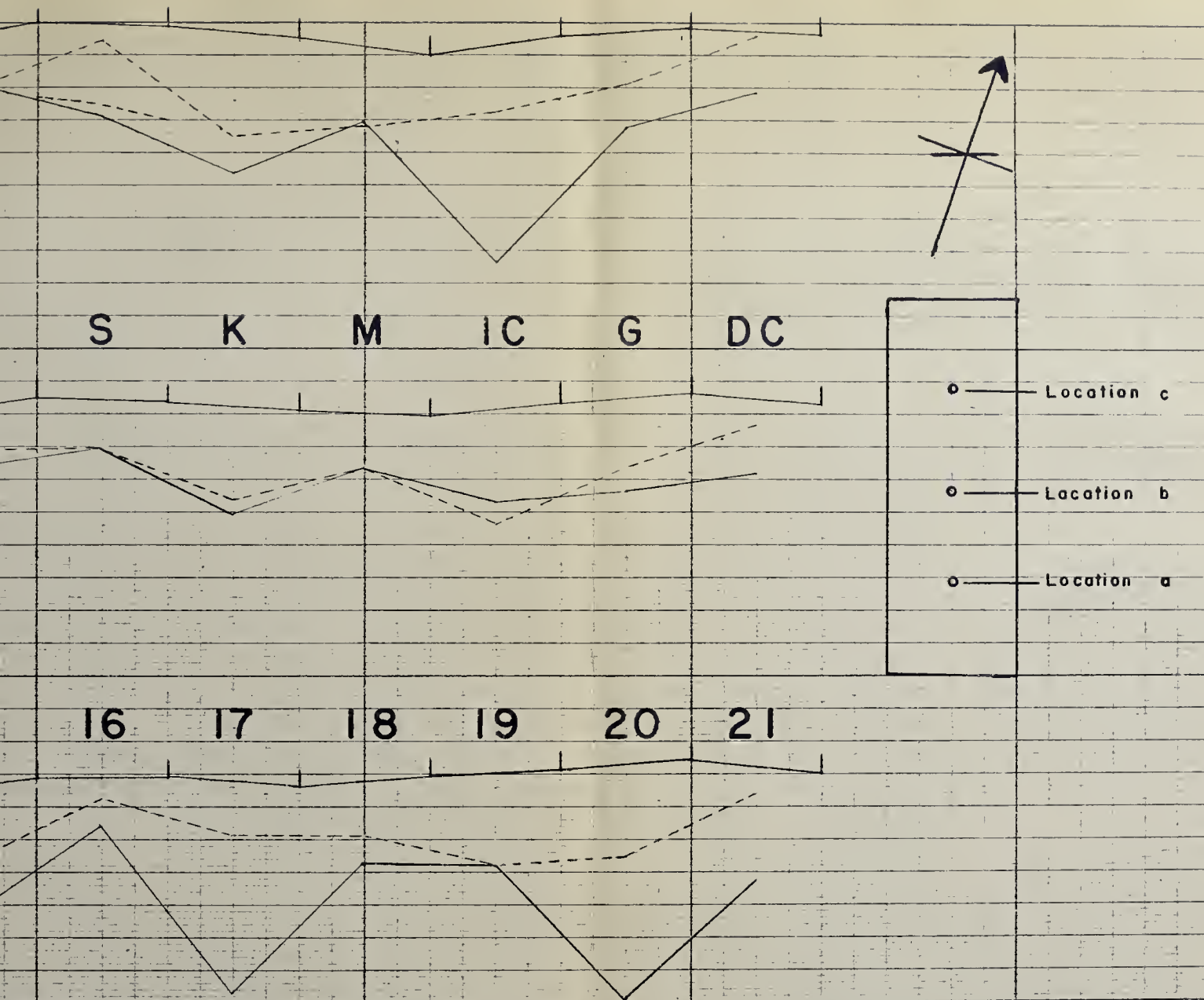
**LEGEND**

Broken line - Isoprobes Sep 1953
 Solid line - Isoprobes June 1953

Soil Penetrometer Isoprobes 1953

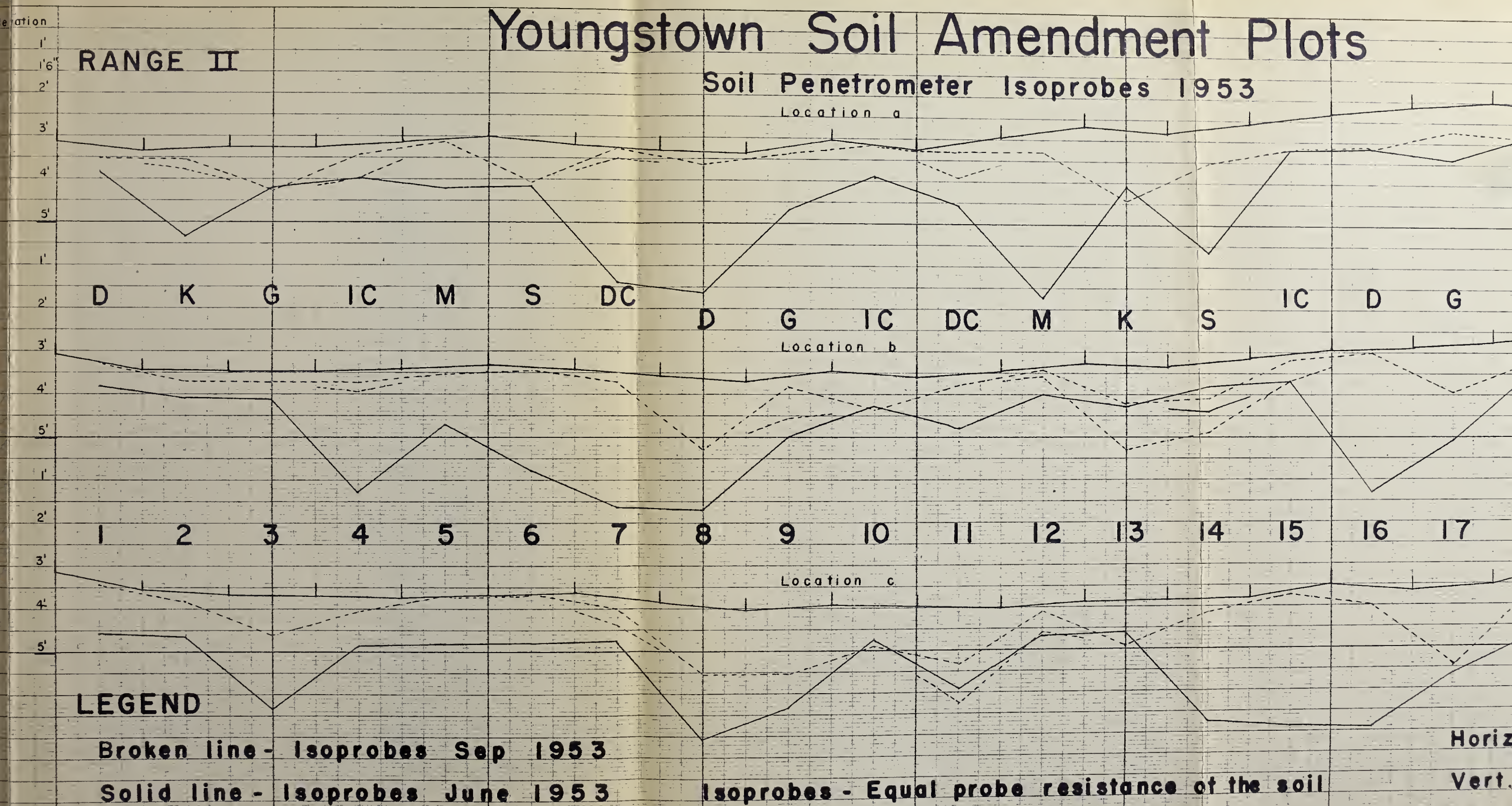
Isoprobes - Equal probe resistance of the soil

Horiz. S
 Vert. S

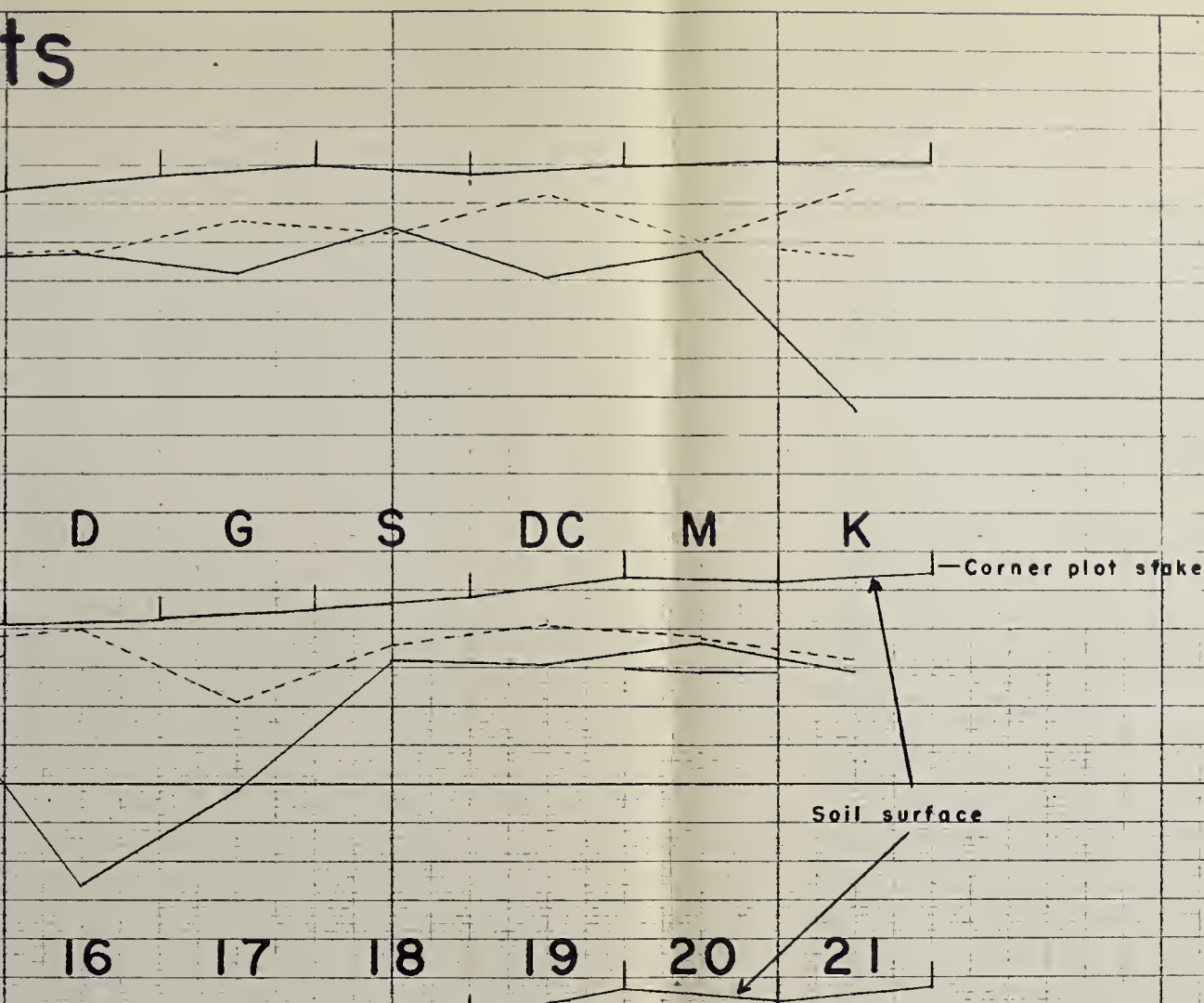


ots

Horiz. Scale 1 inch to 16 feet
Vert. Scale 1 inch to 2 feet

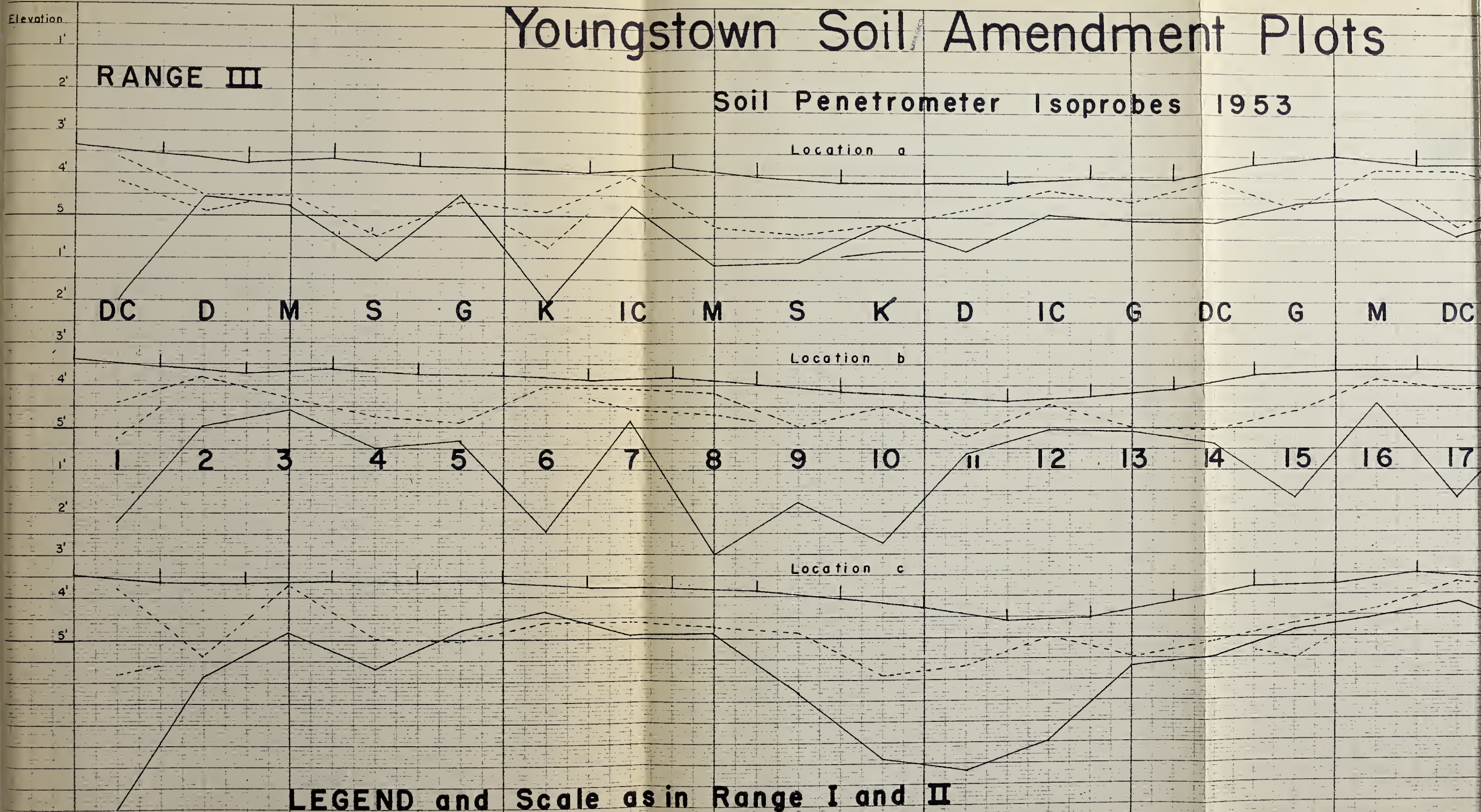


ts

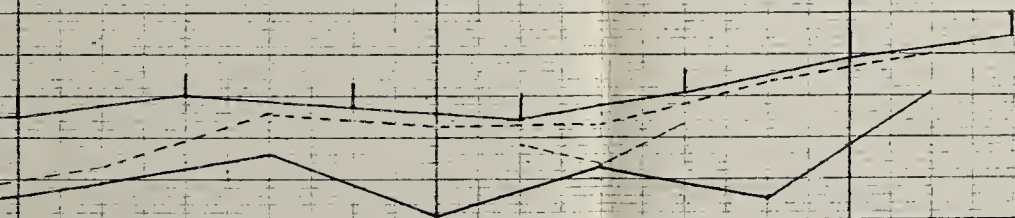
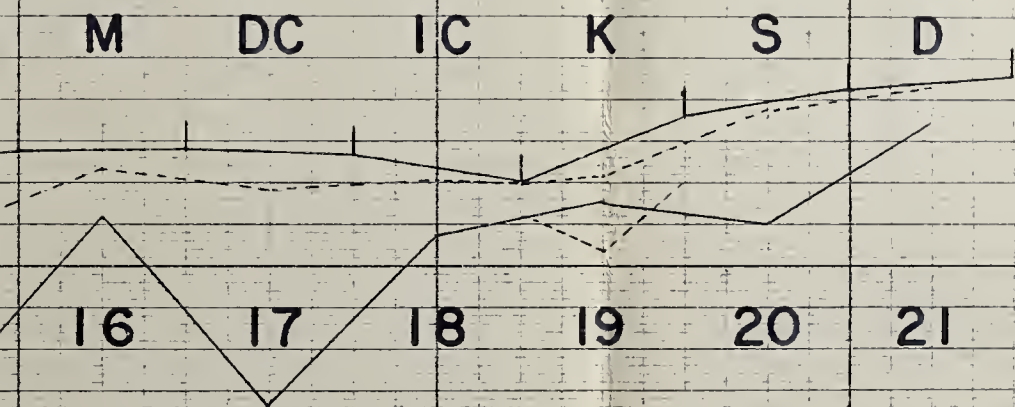
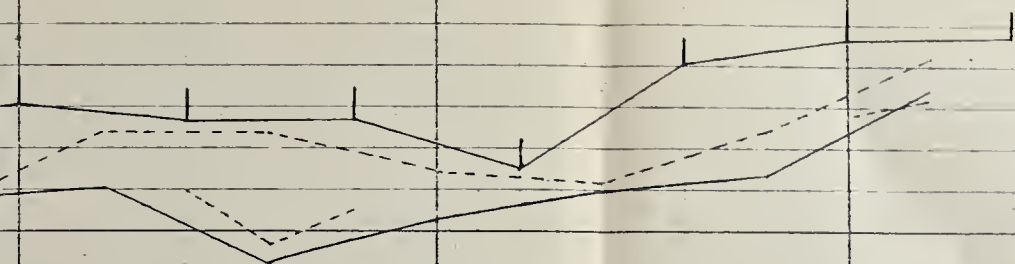


Horiz. Scale 1 inch to 16 feet

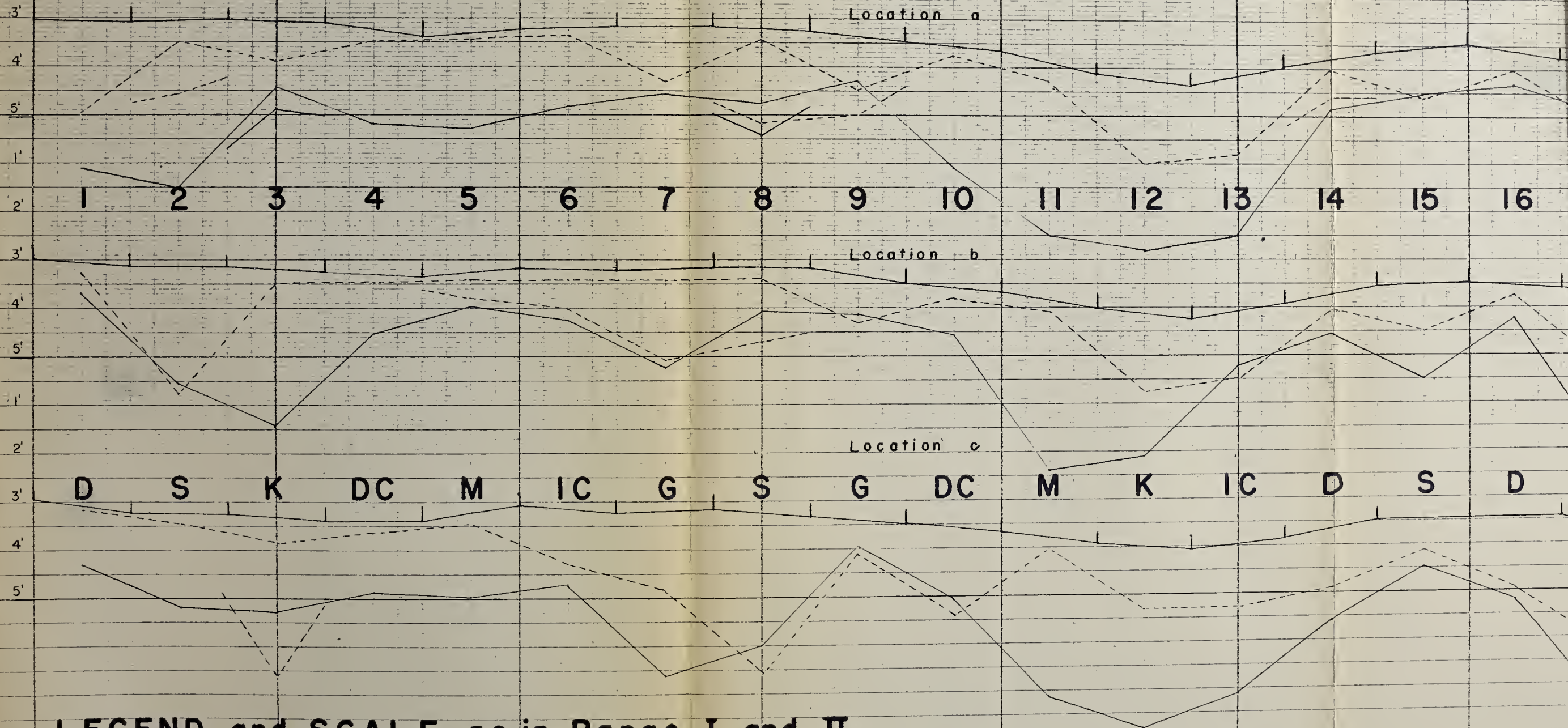
Vert. Scale 1 inch to 2 feet



ots

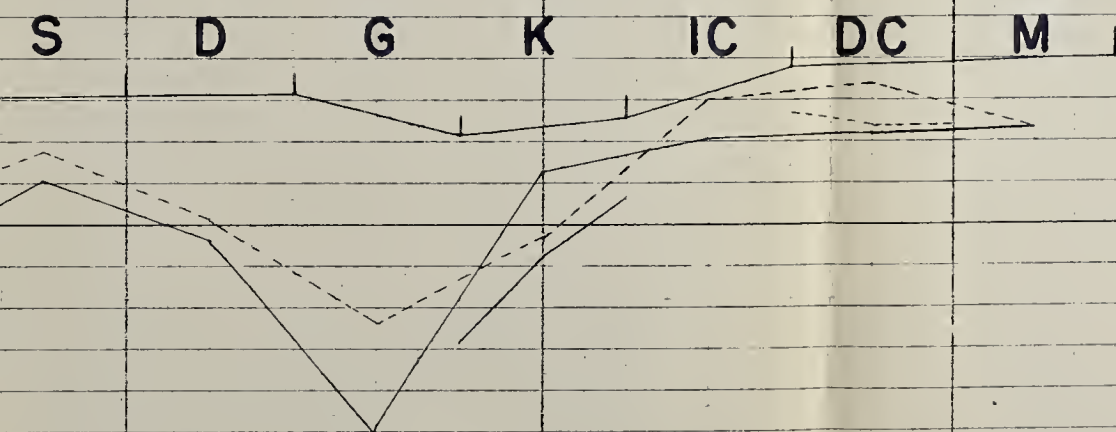
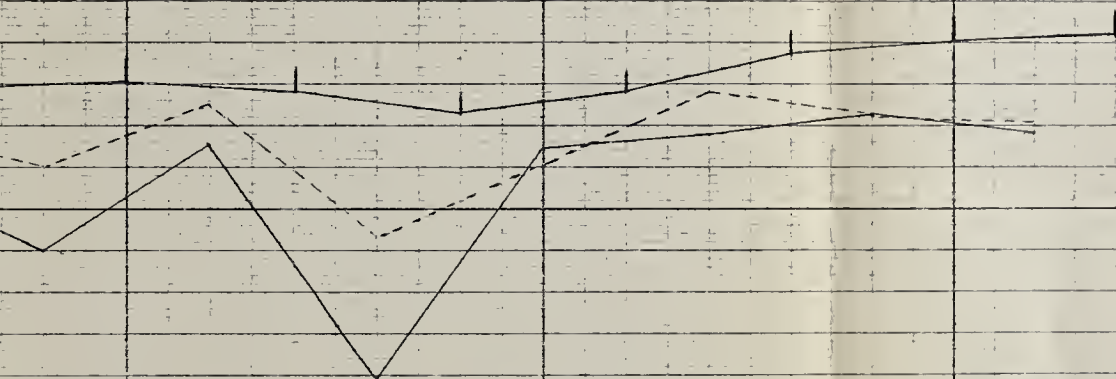
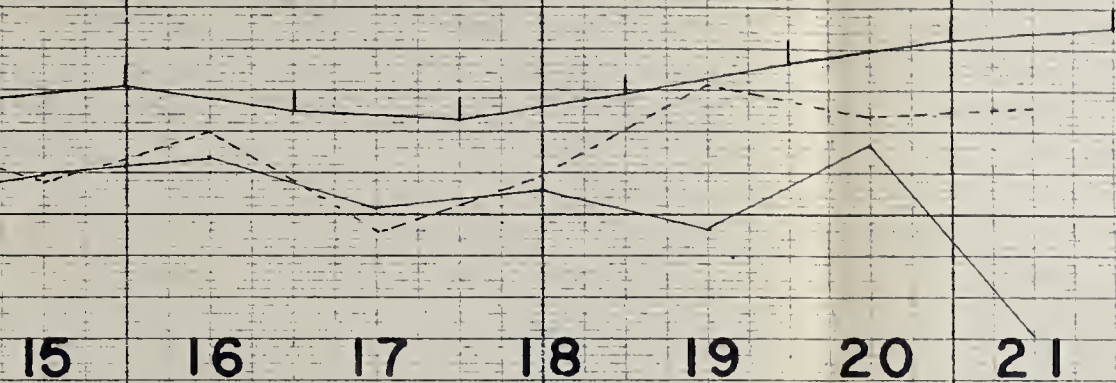


Youngstown Soil Amendment Plots

RANGE IV**Soil Penetrometer Isoprobes 1953****LEGEND and SCALE as in Range I and II**

Plots

3



B29768